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REPORT AND DECISION ON REVIEW OF PLAN FOR MAXIMUM OIL PRODUCTION RATE LIMITATION IN ALBERTA

MARCH 1965

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OIL AND GAS CONSERVATION BOARD

603 SIXTH AVENUE SOUTH WEST • CALGARY, ALBERTA

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I INTRODUCTION

In its report announcing the new plan for proration of oil to market demand,(1) the Oil and Gas Conservation Board stated at page 183, "The Board believes that some form of maximum daily rate restrictions for wells must be retained in the interests of preventing waste and agrees that the present MPR formula is not an ideal basis on which to establish such rates. The Board therefore intends to call a public hearing in the near future to receive submissions on this matter."

The Board discussed the considerations leading to this decision earlier in that report under the heading "Restrictions on Maximum Daily Rates of Production on the basis of GOR, WOR or Lease Boundary Location." After briefly outlining present practices and summarizing the views of industry, the Board stated, "The Board agrees with those in industry who believe that some form of maximum rate restrictions for wells, leases, projects and pools as a whole should be retained in the interests of preventing reservoir waste. Furthermore, in the Board's view, gas-oil ratio and water-oil ratio penalties serve the dual purposes of furtherance of conservation and protection of the interests of other owners. The Board believes that maximum rate restrictions and gas and water penalty restrictions complement one another and that there is no sound reason for discarding either." After referring to the Board's intention of calling a hearing to review methods of establishing maximum rates, the report continued, "Also the Board believes there may be certain minor inconsistencies in its gas-oil ratio penalty tables and intends to review this matter at the same hearing."

---

(1) OGCB Report 64-10. Report and Decision on Review of Plan for Proration of Oil to Market Demand in Alberta. July 1964.

Consequently, on August 14, 1964, the Board announced that it would hold a public hearing commencing November 17, 1964, for the purpose of receiving representations concerning

(a) methods of limiting maximum daily rates of production of crude oil from individual wells and pools,

(b) the use of the rates established pursuant to (a) above for limiting crude oil production from wells and pools not subject to prorating, and

(c) modifications to the Board's policy of limiting monthly production of crude oil from wells on the basis of gas-oil ratio with respect to

(i) the use in appropriate cases of Penalty Tables 200, 400, 600 or 800 (Table 1000 is the lowest schedule now used to restrict gross gas production), and

(ii) the applicability of gas-oil ratio penalty tables in pools or areas where gas, water or other fluids are being injected.

Provision was made in the notice for the filing of primary submissions by October 20 and of submissions of response concerning and related to the particulars of one or more primary submissions on or before November 3.

While the notice specifically referred to the gas-oil ratio factors, full discussion of maximum rate limitation for the prevention of waste necessitated some comment on water-oil ratio factors. A matter raised in the submission of the Board staff and dealt with at the hearing, though perhaps not specifically referred to in the notice, was the basis of selection of the appropriate table in terms of the initial gas-oil ratio in the pool.

Where maximum rate limitations are applied for the prevention of waste, the concern is for underground waste or, to use the phrase in the part of the proration report quoted above, "reservoir waste", and not surface waste.

With respect to the scope of the proceedings, the Chairman in opening the hearing, stated:

"The Board gathers that there has been some misunderstanding as to the intended scope of this hearing. With respect to maximum daily rates of production, the Board considers that matters related to relative rights of owners have already been heard, reviewed and disposed of. I am referring to the proration decision and the regulations concerning production spacing units and block allowables which have now been formulated after discussion with industry. At this hearing views are to be heard on limitation of maximum daily rates of production for the prevention of waste rather than as otherwise may be appropriate for protecting the relative rights of owners.

"The Board takes the position that if, after experience with the new production spacing unit and block allowable regulations, serious questions on correlative rights should arise the present regulations could be reviewed with industry or, if appropriate, a special hearing could be called.

"We note that one of the submissions makes reference to the application upon introduction of the floor allowance plan of gas-oil ratio penalties to the floor allowance. Again, the Board considers this a matter on which a decision has already been given and not one for further discussions at this hearing."

The hearing following the notice was held by the Board on November 17 and 18, 1964.

Appearances

The following presented primary submissions:

Submission by	Represented by	Witnesses for	Abbreviation of names used in this report
Hudson's Bay Oil and Gas Company Limited	C.C.Frye	C.C.Frye	Hudson's Bay
Husky Oil Canada Ltd.	C.G.Chinneck	C.G.Chinneck E.A.Pavan	Husky
Imperial Oil Limited	D.E.Lewis,Q.C. R.Horsfield	R.S.Buckles	Imperial
Board Staff	D.R.Craig N.A.Strom	N.A.Strom	
Socony Mobil Oil of Canada, Ltd.	D.W.MacFarlane P.J.Hoenmans H.Groeneveld	H.Groeneveld	Socony Mobil
Sun Oil Company	J.A.Crate	J.A.Crate	Sun
Whitehall Canadian Oils Ltd.	W.A.Elser	W.A.Elser	Whitehall

All of the above except Husky, the Board staff and Sun also presented responses to submissions and Imperial presented a rebuttal. In addition, responses to submissions were presented by the following:

Response by	Represented by	Witnesses for	Abbreviation of name used in this Report
Amerada Petroleum Corporation	R.P.Cummer	R.P.Cummer	Amerada
The British American Oil Company Limited	A.Janisch	J.B.McDonald	British American
Canadian Pacific Oil and Gas Limited	R.G.Farquharson	R.G.Farquharson	CPOG
The California Standard Company	L.C.Zerr	L.C.Zerr	California Standard
Dome Petroleum Limited	M.E.McElroy	M.E.McElroy	Dome
Home Oil Company Limited	J.H.Siferd	J.H.Siferd	Home
Great Plains Development Company of Canada, Ltd.	L.Samoil	L.Samoil	Great Plains
Pacific Petroleums Ltd.	G.E.Nickoloff	G.E.Nickoloff	Pacific
Pan American Petroleum Corporation	W.G.Trimble F.F.Craig,Jr.	W.G.Trimble F.F.Craig,Jr.	Pan American
Shell Canada Limited	J.M.Killey M.M.Durham	M.M.Durham	Shell
Texaco Exploration Company	R.Pike	R.Pike	Texaco Exploration
Triad Oil Co. Ltd.	J.R.Lacey R.G.Kessler	J.R.Lacey R.G.Kessler	Triad
Skelly Oil Company	G.W.Selinger	I.Ruus	Skelly

In conclusion, brief oral arguments were made on behalf of Socony Mobil and Triad.

Glossary

The following definitions apply to terms used in this report unless the context otherwise indicates:

drainable areas - a term used by Imperial - pools or portions of pools which, for all practical purposes, act independently during their depletion lives.

gas-oil ratio or GOR - the number of cubic feet of gas produced with each barrel of oil produced.

heavy crude oil - crude oil of which the gravity rating by the American Petroleum Institute scale is 25° or a lesser number, but a greater or lesser gravity may be used depending on whether the crude oil is utilized in a market distinct from that satisfied by light and medium crude oil.

light and medium crude oil - crude oil other than heavy crude oil.

Maximum Efficient Rate or MER - the maximum rate at which oil can be produced without avoidable underground waste.

Maximum Monthly Rate or MMR - a term used by Imperial - a maximum rate limitation applied on a monthly basis and expressed as the number of barrels of crude oil that may be produced from a drainable area during a month.

Maximum Permissible Rate or MPR (for an individual well) - the Board's estimate of the MER of the average well in a pool.

Maximum rate limitation or MRL - a general term used in connection with individual wells, portions of pools or pools.

net gas-oil ratio or net GOR - the ratio of the volume of gas produced less the gas returned to the reservoir, expressed in cubic feet, to each barrel of oil produced.

new pool - a pool that will be discovered in the future.

old pool - a pool already discovered at the date of the Board's decision given in this report.

pool MPR - the Board's estimate of the pool MER.

Preliminary Rate Limitation or PRL - the Board's preliminary or initial estimate of the MRL applicable to a portion of a pool or a pool.

ultimate reserves - the remaining reserves of a pool plus the volume of oil that has been produced from the pool.

water-oil ratio or WOR - the number of barrels of water produced with each barrel of oil produced.

II PROVISIONS OF STATUTE AND REGULATIONS

Section 35, subsection (1), clause (d) of The Oil and Gas Conservation Act states,

> 35. (1) The Board may, by general or special orders,
>
> ....
>
> (d) control and regulate the production of oil, gas and water by restriction, proration and prohibition,
>
> ....

This provision in section 35, taken alone, would give the Board unrestricted power for the establishment of maximum rates of production and the application of gas-oil and water-oil factors. Inasmuch as a purpose for the control or regulation of production is not specified, the Board, in exercising the power to restrict production, would look to section 4 of the Act for the purpose. This section reads as follows:

> 4. The intent and purpose of this Act are
>
> (a) to effect the conservation of the oil and gas resources of the Province,
>
> (b) to prevent the waste of the oil and gas resources of the Province,
>
> (c) to secure the observance of safe and efficient practices in the locating, spacing, drilling, equipping, completing, reworking, testing, operating and abandonment of wells and in all operations for the production of oil and gas, and

> (d) to afford to each owner the opportunity of obtaining his just and equitable share of the production of any pool.

Clause (b) of section 4 is particularly significant and to consider how it applies two of the definitions appearing in section 2 of the Act should be considered. They are the definition of "waste" which is quoted below and the definition of "wasteful operations" of which the relevant parts are quoted.

> 2. (t) "waste", in addition to its ordinary meaning, means "waste" as that term is understood in the oil and gas industry, and includes the underground or surface loss through wasteful operations of oil or gas or of potentially recoverable oil or gas;
>
> (u) "wasteful operations" means
>
> (i) the locating, spacing, drilling, equipping, completing, operating or producing of a well in a manner that results or tends to result in reducing the quantity of oil or gas ultimately recoverable from a pool under sound engineering and economic principles,
>
> ....
>
> (iii) the inefficient, excessive or improper use or dissipation of reservoir energy however caused,
>
> ....

While the need for maximum rate restrictions and the application of gas-oil ratio and water-oil ratio factors are discussed in Sections III and VI of this report, it may be stated briefly that the objective of maximum rate limitations is to prevent the production of a pool or part thereof in a manner that results or tends to result in reducing the quantities of oil or gas ultimately recoverable from the pool. Maximum rate limitation is therefore related to the prevention of the wasteful operations referred to in subclause (i) of the definition of wasteful operations. Gas-oil ratio and water-oil ratio restrictions are applied not only for the protection of correlative rights but also for the prevention of unnecessary dissipation of reservoir energy. Thus they aid in the prevention of the wasteful operations referred to in subclause (iii) of the definition of wasteful operations.

The manner in which maximum rate restrictions and gas-oil and water-oil ratio factors are now applied is in accordance with announced policies of the Board and is described in Section VI of this report. Schedules of the factors that may be applied, both those based on gas-oil ratios and those based on water-oil ratios, appear in the First Schedule to the General Regulations under The Oil and Gas Conservation Act and are also included in the Appendices to this report.

III THE NEED FOR POOL AND INDIVIDUAL WELL MAXIMUM RATE LIMITATION

Sensitivity of Recovery to Production Rate

In a consideration of the need for maximum rate limitation for pools, portions of pools and individual wells in the interest of preventing underground waste the two matters of concern are the sensitivity or otherwise of pool recovery to pool production rate and of pool recovery to individual well production rate. The views of industry and the Board on these separate matters and the overall view of the Board are presented in the following.

1. Sensitivity of Pool Recovery to Pool Production Rate

(1) Views of Industry

Several companies considered the effect of rate of production on recovery in their submissions or responses or testified at the hearing in this regard.

Imperial stated that the concept of maximum rate limitation for prevention of waste is predicated on the belief that oil recovery is generally rate sensitive. It submitted that such factors as gravity drainage, pressure control and imbibition (usually associated with rate sensitivity) can be very influential at extreme rates of production but are relatively insensitive to rate in the practical range. It further stated that a maximum rate limitation is not an invariant characteristic of a reservoir, but is dependent on the recovery mechanism employed as well as on the physical nature of the reservoir, its surroundings and contained fluids.

In regard to water drive reservoirs, Imperial stated oil displacement is known to be affected by a great many factors including fluid and formation properties, gravity, initial free gas saturations and rate. In vertical systems Imperial contended that except at extremely high rates the normal density contrast between oil and water is more than sufficient to balance the vertical pressure gradients induced by flow and this has a marked tendency to promote uniformity of the advancing displacement front. However, Imperial added gravity control is a factor deserving more consideration near the late stages of depletion. Imperial stated that imbibition is a factor which can be of importance in any water drive system since the process is time dependent and suggested that as in gravity control its importance increases with the depletion of the pool. It added that pressure control can also be an important factor related to maximum rate limitation, particularly where water drive does not adequately keep pace with pool withdrawals.

Imperial stated that in the case of solution gas drive reservoirs producing within the practical range of rates, the recovery is not characteristically sensitive to rate. It also stated that, in most cases, maximum rate criteria which can be safely applied to water drive pools should also be safe for gas drive pools and that combination drive pools (both gas cap and underlying water) are generally similar to the water drive pools.

Imperial submitted that in pattern floods a certain degree of rate sensitivity can develop which would be significant with regard to ultimate recovery.

Imperial concluded that a wide variety of results is possible ranging from unlimited rate levels for solution gas drive to only moderately high rate levels where water or combination drive is the controlling mechanism.

Socony Mobil suggested that certain pools may become rate sensitive within particular limits but emphasized that the effect on recovery is difficult to ascertain. The company said that many pools are not rate sensitive and do not have a maximum efficient rate. Socony Mobil, however, in apparent agreement with Imperial, stated that there could be a significant rate effect on recovery in late stages of pool depletion.

Amerada, Dome, CPOG, Pan American and Shell contended that recoveries from solution gas drive reservoirs are not rate sensitive and that waste could occur only at extreme rates of production. Amerada agreed that few reservoirs are depleted by solution gas drive mechanism alone. Dome questioned the certainty with which a maximum efficient rate for solution gas drive reservoirs could be calculated and questioned its existence.

(2) Views of the Board

The Board agrees with industry that the type of drive or recovery mechanism is the important factor in the consideration of rate sensitivity.

Oil Expansion Drive. The Board believes that recovery of oil through reservoir depletion by oil expansion down to the bubble point pressure is not rate sensitive.

Solution Gas Drive. The Board agrees with the views of industry that the recovery of oil from relatively uniform reservoirs producing under a solution gas drive mechanism is independent of pool production rate within practical limits. The Board is convinced, however, that stratified reservoirs and cases where withdrawals are disproportionate with local oil-in-place require special consideration. In these pools high rates of production may result in pressure differentials which could lead to unequal oil desaturation and excessive gas-oil ratios. The extent to which a desirable saturation redistribution is possible during reasonable time limits depends upon reservoir permeability, fluid viscosity and pool production rate.

Furthermore, the depletion of a heterogeneous reservoir at high rates of production by solution gas drive can establish saturation conditions which would result in still more detrimental effects during any subsequent displacement by water.

Displacement by Water. In the case of oil displacement by water, the Board agrees with Imperial that recovery of oil from even relatively uniform reservoirs is to some extent affected by rate of production. The water displaces oil in the main flow channels at the rate of frontal advance, but oil in the interconnecting small pores remains controlled by capillary forces. Oil may be recovered from these small pores by imbibition, a phenomenon which occurs at its own rate independent of applied external forces. At low production rates, but still within the economically practical range, oil recovered by imbibition from small pores could be significant. In addition, where there is substantial permeability variation, high production rates could distort water fronts and leave oil unrecovered. Channelling, by-passing or trapping of oil by water are more pronounced at high rates than at low rates where capillary forces have time to improve the uniformity of frontal advance. At low rates, gravity forces may operate to the detriment of uniform frontal advance where the displacement is horizontal, but may promote uniformity where the displacement is vertical. In communicating zones, cross-flow may improve the volumetric sweep efficiency and aid pool recovery. The amount of water that can enter zones of low permeability to displace oil, will depend upon reservoir geometry, effective permeability and rate of production.

Displacement by Gas. As in the case of displacement of oil by water, the Board agrees with Imperial that the displacement of oil by gas in relatively uniform reservoirs is somewhat sensitive to production rate. While there is no effect comparable to imbibition by water, gravity forces may lead to conditions where recovery by gas displacement would be rate sensitive. Where there is a large variation in permeability, mobility ratio effects further distort fluid fronts and increase the sensitivity of pool recovery to rate of production, as in the case of displacement by water.

Displacement by Miscible Fluid. The Board believes that the effectiveness of displacement by miscible fluid is rate sensitive because of the time dependency of molecular diffusion, mechanical mixing, gravity segregation and viscous fingering effects. Since oil recovery from dead-end pores by diffusion is dependent on concentration gradients and the time during which these gradients are active, displacement efficiency and recovery depend upon production rate. Mechanical mixing and gravity segregation effects are rate sensitive phenomena which can influence the effectiveness of the miscible fluid, the displacement efficiency and the pool recovery. Transverse diffusion between fingers, a time dependent process, modifies front profiles, improves sweep efficiency and affects pool recovery.

Combination Drives. The Board believes that in the usual case of several active drives, rate may affect pool recovery through both its influence on the effectiveness of each drive and the control of drive participation in the combined recovery mechanism. Rate control can often reduce the role of an inferior type of drive and, under special circumstances, augment the activity and efficiency of the most desirable drive or combination of possible drives. In this way, loss of recoverable oil is prevented.

Summary. Reservoir engineering theory, laboratory experiments and field observations confirm that underground waste in the reservoir as a whole may result from the production of a pool or portions of it at excessive rates. Sensitivity of pool recovery to production rate is in the last analysis dependent upon the effect of rate on displacement and sweep efficiencies in the presence of capillary and gravity forces and concentration gradients. The effectiveness of these phenomena varies in accordance with the reservoir drive mechanism.

2. Sensitivity of Pool Recovery to Individual Well Production Rate

(1) Views of Industry

Only a few companies referred specifically to the sensitivity of pool recovery to individual well production rate.

Imperial stated that maximum rate limitation has significance only when applied to individual drainable areas and emphasized that any arbitrary division of such MRL's into individual well or production spacing unit MRL's has no real meaning. Imperial took the position that the recovery of oil is completely independent of the individual well drawdowns, individual well rates or individual well sandface effects generally.

Amerada suggested that the individual well rate would be significant only in a few special cases.

CPOG submitted that excess gas and water production appears to be rate sensitive.

(2) Views of the Board

The Board believes that water and gas coning and local encroachment of active water are affected by well drawdowns and must be considered rate sensitive. The Board, however, agrees with those in industry who contend that rate sensitive well performance does not necessarily lead to loss of recovery from the pool. Nevertheless, the Board believes that under special conditions the individual well rate can affect the recovery from the pool. Segmentation of a pool by either irregular fluid interfaces or reservoir pressure sinks and local effects rendering a well ineffective in the process of producing the recoverable oil from its allocated spacing area over a reasonable time interval, are circumstances which can be prevented or controlled by individual well rate limitations. The Board believes that individual well rate limitations may aid in the prevention of coning and channelling, or the elimination of excessive localized drainage and irregular fluid interfaces. Where such special conditions prevail, individual wells become important to the effective drainage of the reservoir since oil which otherwise would be recovered by them may not be produced by other wells in the pool.

3. Overall Board View

Having regard to its belief that pool recovery may be influenced either by pool rates in excess of those permitting efficient oil displacement in the reservoir as a whole or by individual well rates leading to dissipation of reservoir energy or impaired local displacement, the Board sees the overall situation as illustrated in Figure 1. This figure is a schematic representation of the interrelationship of the two factors which may influence the MER of a pool. For a pool of given characteristics and producing under a given recovery mechanism, there is a "reservoir" MER independent of individual well effects, which at any particular stage of depletion is constant regardless of spacing. This is indicated by line ABC, on the figure. Similarly, for each well there is in principle an "individual well" MER, and therefore a summation of "individual well" MER's, which varies almost inversely with spacing. This is indicated by line DBE on the figure. The well spacing corresponding with the point of intersection, B, depends upon the reservoir rock characteristics, the mobility of the reservoir fluids and the recovery mechanism. In many practical cases this spacing is well in excess of that in effect. Where the actual spacing is closer than that corresponding with B, the pool MER is the "reservoir" MER. On the other hand, where the actual spacing is wider than that corresponding with B, the pool MER is really determined by the summation of the "individual well" MER's. Thus, in general, the relationship between pool MER and spacing, for a given pool, takes the form of line ABE.

While the Board agrees with what it understands to be the position of industry, i.e. that the "reservoir" MER will in most cases control the pool MER, the Board believes that this may not be the case in thin pay or low permeability pools with wide well spacing. Furthermore, and however the pool MER may be established, the Board considers that in addition there may be special cases where loss of pool recovery could result from excessive rates of production at individual wells, even when the withdrawals from the pool as a whole are not in excess of the pool MER.

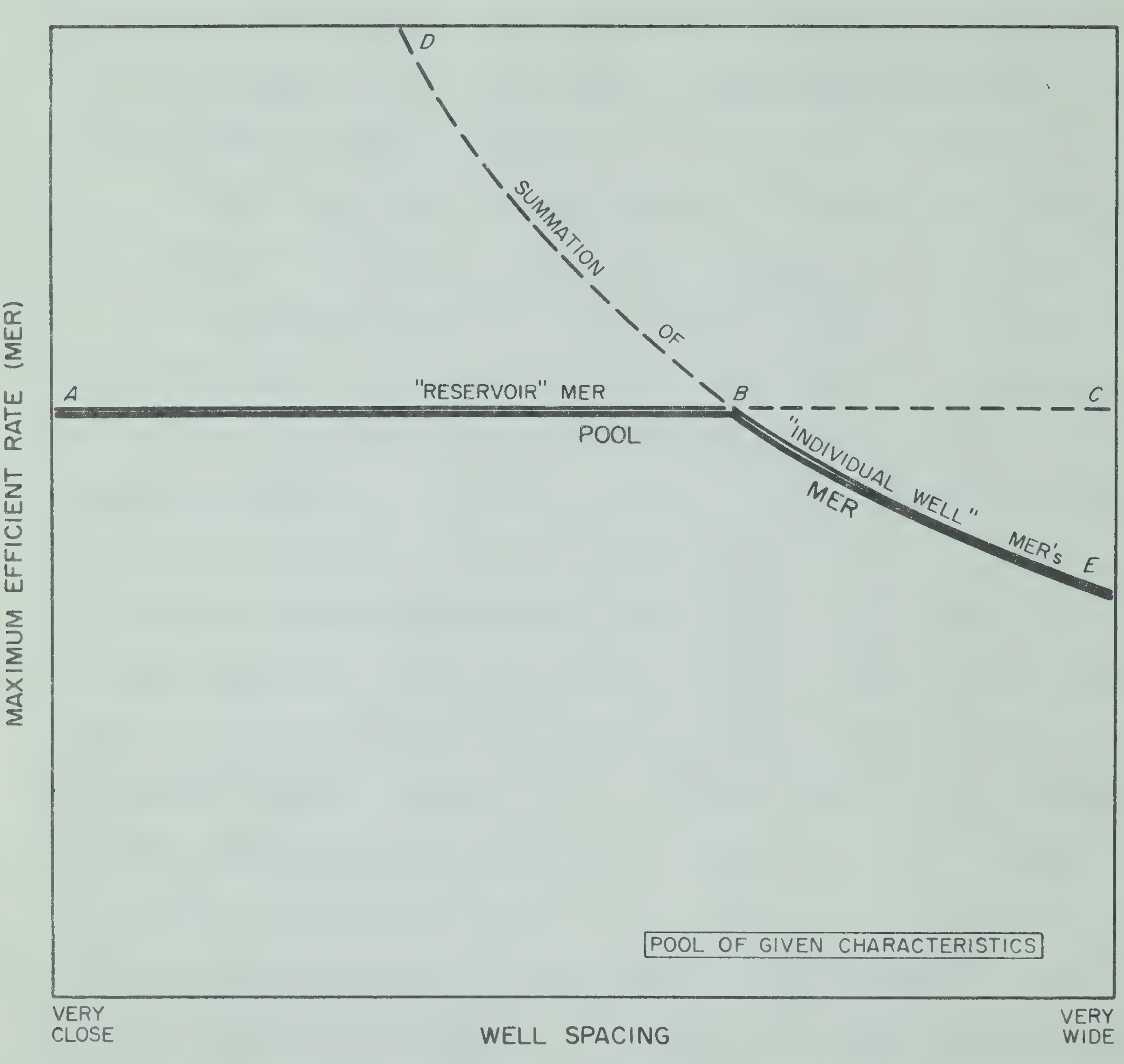

FIGURE I - SCHEMATIC DIAGRAM SHOWING RELATIONSHIP BETWEEN POOL MER, "RESERVOIR" MER, SUMMATION OF "INDIVIDUAL WELL" MER's AND WELL SPACING FOR A POOL OF GIVEN CHARACTERISTICS

The Need for Maximum Rate Limitation in Pools and Portions of Pools

1. Pools Subject to Prorating

(1) Views of Industry

Most of the participants in the hearing accepted the need for selective application of pool rate limitations to prevent waste; but as to the need for a uniform and general plan for maximum rate limitations, the opinions expressed varied greatly.

Husky, CPOG, Great Plains, Pacific, Pan American and Shell supported the concept that maximum rate limitations are needed to prevent loss of recoverable oil.

Nine companies - Imperial, Amerada, British American, CPOG, California Standard, Dome, Pacific, Pan American and Shell - expressed favour for "preventive" measures; six companies - Socony Mobil, Sun, Whitehall, Home, Great Plains and Texaco Exploration - thought the objectives should be "remedial" in scope; three companies - Hudson's Bay, Husky and Skelly - did not take any position regarding implementation of maximum rate limitations; and one company - Triad - opposed any form of a plan for rate limitation.

Imperial stated that maximum rate limitation is necessary for prevention of underground waste. The company stated that it could not subscribe to the generalization that proration allowables are sufficient limitation on production. Imperial proposed an initial rate limitation intended to serve as a safeguard to preclude the possibility of underground waste until an MRL could be established on an engineering and individual case basis. This company emphasized that the maximum rate limitation for the prevention of waste should override the proration allowables.

Amerada, in its response, generally acknowledged the need for a safe rate limitation as proposed by Imperial, but contended that solution gas drive reservoirs should be exempt from any such rate restriction. Amerada expressed the belief that the need for a pool maximum rate limitation in other types of pools should be ascertained on an individual basis.

British American supported the concept of rate restrictions on a pool or drainable area basis by limiting the monthly production where necessary, in accordance with a maximum efficient rate determined through engineering knowledge. British American implied that MRL's are needed to prevent high producing rates at which avoidable underground waste would occur. The company accepted the need for a maximum producing rate of the type proposed by Imperial only as a substitute for an MER for those pools where it is impractical or premature to establish such an MER.

California Standard, while apparently accepting the need for a pool rate limitation, took the position that the maximum rate should be related to the proration allowable in such a way as to permit liberal flexibility in production operations.

Dome supported the safe rate limitation concept recommended by Imperial, and suggested that solution gas drive reservoirs may not need rate restrictions. Dome agreed that, depending primarily upon driving mechanisms, maximum rate limitations are applicable to some pools.

Pacific generally supported the safety concept embodied in the rate limitation proposed by Imperial, but did not see any need for detailed implementation such as on a flood pattern basis.

Pan American accepted the need for a multi-well rate restriction as implied in Imperial's safe rate limitation concept and referred to areas of like recovery mechanisms as being significant in the implementation of any rate limitation.

Shell supported Imperial's safe rate concept and, implicitly, the need for a rate limitation for pools or parts thereof.

Socony Mobil rejected the use of safe rate limitations calculated from general formulas, on the basis that such rates would be as arbitrary as production allowables themselves. This company contended that in the current system the production rate is often limited to avoid underground waste but that many pools and wells in Alberta could produce at higher rates without a reduction in ultimate recovery from the pool. Socony Mobil, while rejecting the general use of rate restrictions, agreed that maximum rate limitation for certain pools or portions of pools may still be required for the prevention of underground waste. The company submitted that a pool production rate should not be restricted until the need for it had been proved by experience, and that the magnitude of the rate limitation should be based on reservoir characteristics and performance history. Socony Mobil, differentiating between pool and well rate limitations, submitted that while restrictions within a pool are related to equity rather than conservation, pool rate restrictions are required for the prevention of underground waste.

Home in its response criticized the use of maximum rate limitations determined from general formulas. This company agreed that certain pools should be restricted by maximum rate limitations, but agreed with Socony Mobil that the need for rate limitation must be proved in any particular case.

Great Plains agreed that maximum rate limitations are necessary for prevention of waste in certain pools such as bottom water drive pools having thin oil columns. The company stated, however, that there is no general need for rate restrictions since the proration system will act as a shield "presently and in the foreseeable future". Great Plains inferred that limitations derived from the implementation of a general formula would be as arbitrary as the proration allowables.

Hudson's Bay, while agreeing that limits are needed to prevent waste or facilitate equitable withdrawals in particular cases, stated that allowables established through the proration plan are a sufficient limitation of production rate and there is no need for overriding maximum rates. This company expressed the belief that there may be a need for maximum rate limitations in pools where there is substantial reallocation of production because of extreme gas-oil ratio penalties or where widespread coning may affect recovery. Hudson's Bay did not agree with Imperial that there is general need for initial safe rate limitations or rate restrictions for individual flood patterns.

Skelly took a distinct position regarding need for maximum rate limitation by implying that any pertinent policy should encourage implementation of the most appropriate of possible enhanced recovery programs.

(2) Views of the Board

The Board agrees with the majority of those giving evidence at the hearing to the effect that pool MRL's are necessary to prevent waste which may take place throughout the entire or substantial portions of a reservoir.

Having regard to the preceding discussions and the difference in concept between proration allowables and MRL's, the Board does not believe that proration allowables could be substituted for MRL's. In addition, the Board concludes that MRL's should not be related to proration allowables in any way and expresses its disagreement with California Standard in this regard.

The Board agrees with the participants in the hearing believing that there is no universally applicable formula for the determination of pool MER's. The determination of specific pool MER's requires representative reservoir fluid and rock data, significant performance history and detailed knowledge of recovery processes, and therefore time to evaluate a newly discovered pool. Consequently, the Board is concerned with the proper protection of pools against detrimentally high rates, until an MER can be determined. This indicates a need for a method of ensuring that pool rates are not excessive and presumably for a procedure of calculating safe MRL's in the early years of the pool life. Whether or not a generally applicable formula for the calculation of such MRL's can be devised, the Board is confident that the application of sound engineering principles will provide guidance to the establishment of appropriate rates.

The Board believes there should be a Province-wide policy based upon sound engineering considerations and clearly and exclusively directed at the elimination of underground waste. In the Board's opinion such a policy should permit proper consideration of reservoir or individual well peculiarities and should not result in pool rate limitation except where necessary for the prevention of economically avoidable waste. Furthermore, the policy should be simple to administer.

2. Pools not Subject to Prorating

General

(1) Views of Industry

Hudson's Bay, Imperial, Socony Mobil, British American, Dome, Pacific, Shell and Texaco Exploration supported the view that in a consideration of maximum rate limitation, unprorated pools should be treated in the same manner as prorated pools.

Hudson's Bay anticipated, however, that few unprorated pools need be rate restricted having regard to the relative importance of economics and recovery.

Whitehall contended that unprorated pools should not be subject to maximum rate limitations unless demonstrated to be necessary for elimination of waste and improvement of recovery.

California Standard favoured good engineering practices and liberal rate restrictions.

(2) Views of the Board

The Board, having regard to the concepts underlying the need for pool MRL's agrees with companies contending that, in principle, there is no difference in the need for MRL's in prorated and unprorated pools.

Heavy Crude Oil

(1) Views of Industry

Husky contended that a general formula for establishing maximum well rates would likely cause inequities between light and medium crude oil and heavy crude oil. The company, while recognizing that in general some restriction is desirable, did not see a specific need for maximum rate limitations applicable to pools producing heavy crude oil.

CPOG agreed that rate restrictions are indeed needed in particular cases to eliminate avoidable loss in ultimate recovery.

British American, while advocating that unprorated light and medium crude oil pools be subject to the maximum rate restrictions applicable to prorated pools, recommended that heavy gravity asphaltic oil pools, of the Lloydminster type, be exempt.

Great Plains proposed that only the "Lloydminster type" of production be exempt from maximum rate limitations.

Whitehall proposed that Husky's recommendation regarding establishment of special limiting rates for the Lloydminster heavy crude oil reservoirs should be considered at the stage when reservoir data and production history are available for the establishment of MER's.

Imperial submitted that there are no reasons for exempting heavy crude oil reservoirs from rate limitation requirements.

Several companies appeared to consider heavy crude oil reservoirs in the same category as unprorated pools and did not submit specific recommendations.

(2) Views of the Board

The Board recognizes that heavy crude oil pools have their own peculiarities in terms of high viscosity and drawdowns, sand and shale sloughing, long flood-out times and related production problems. In the Board's opinion, however, the differences between heavy crude oil and light and medium crude oil pools are of degree rather than kind. The Board agrees with Imperial that arguments for special consideration of Lloydminster type pools are pertinent to the establishment of an individual pool MRL rather than to the design of a general plan for maximum oil production rate limitation.

The Board concludes that the same basic principles regarding the need for maximum rate limitation in pools should apply to light, medium and heavy crude oil pools.

The Need for Individual Well Maximum Rate Limitation

1. General

(1) Views of Industry

Of the companies participating in the hearing, only

Whitehall saw a need for individual well rate limitation on a general basis, and only it indicated objectives of such limitation.

Whitehall contended that, in the absence of other limitations, a well MRL is needed to effect conservation generally, preserve equities and minimize reservoir drainage under extreme conditions of transfer of allowables. The company, however, expressed favour for a remedial approach in the implementation of individual well rate restrictions.

Hudson's Bay contended that, excepting restrictions for injection-production balance, individual well rate limitations are unnecessary.

Husky contended that well bore conditions appearing to indicate damage, do not necessarily result in loss of recoverable oil from the pool, and each case must be tested and analysed individually.

Imperial stated that individual well rate restrictions are not required for the prevention of underground waste.

Socony Mobil rejected a general need for individual well MRL's but agreed that in certain circumstances high well rates could be detrimental to ultimate recovery.

Sun stated that a discontinuation of maximum permissive rates for oil wells would not have an adverse effect on conservation but might present a problem of lease boundary drainage. The company, however, agreed that individual well MRL's could be needed, should the proration allowables increase substantially.

Amerada opposed individual well MRL's on a general basis but accepted that well rates are significant in a few special cases.

British American questioned the need for individual well rate limitations by contending that the system of proration allowables provides sufficient incentive against rates leading to undesirable conditions near wells.

Dome expressed the belief that well bore production mechanisms suggest the need for maximum rate limitations only in extreme cases.

Pan American submitted that gas-oil and water-oil ratio penalties and lease boundary controls are sufficient precautions in terms of individual well rate limitation. This company reiterated that individual well limitations are unnecessary and impractical. Pan American, however, agreed that individual well maximum efficient rates indeed exist and that cases may occur where a high well rate would cause reservoir damage and underground waste. Pan American testified that the individual well MER may be related primarily to the reservoir and its recovery mechanism, rather than the well itself.

Shell questioned the validity of calculated maximum efficient rates for individual wells.

Texaco Exploration contended that underground waste caused by conditions at the well bore can occur only in a limited number of cases and it can be prevented without implemention of individual well rate limitations.

Triad referred to practical restrictions of individual well production and, except for lease boundary wells, opposed individual well rate restrictions.

From the above and additional testimony at the hearing, it is clear that the industry, while opposing a general application of MRL's on an individual well basis, agreed that individual well MRL's may be desirable in exceptional cases. Drawing from all the views expressed, the objectives appeared to be

(a) avoidance of reduction of pool recovery by safeguarding the productivity of wells required for recovery,

(b) avoidance of recovery loss by widespread gas or water coning or, in the case of thin column reservoirs, by water encroachment,

(c) elimination of shrinkage of gas-cap because of extensive gas channelling,

(d) prevention of excessive pressure drawdowns leading to formation of zones or channels of high gas saturation and thus avoiding preferential gas flow.

(2) Views of the Board

The Board agrees with industry that individual well MRL's are not required on a general basis but that in special circumstances they may be necessary to prevent loss of recovery from areas which cannot be served effectively by any other wells completed in the same pool. While the functions of gas-oil ratio and water-oil ratio controls are discussed separately, it may be stated at this time that the Board believes these controls help minimize coning and other conditions leading to a loss of recovery from the entire or substantial portions of a pool. Cases exist, however, where prevention of gas and water coning is both desirable and possible at practical rates. The occurrence of these cases suggests that GOR and WOR controls may not in themselves be adequate and individual well MRL's may have to be instituted to reduce individual well rates below that which would result in a pressure drawdown causing coning.

2. Control Wells

(1) Views of Industry

Several participants recommended that maximum rate limitations be applied to control wells offsetting competitive lease boundaries to protect owner rights.

Hudson's Bay stressed production limitation of wells in areas offsetting competitive lease boundaries.

Socony Mobil expressed the belief that rate restrictions within a pool are related to equity rather than conservation and stated that conservation concepts should not be used as excuses to achieve equities. The company strongly argued that the maintenance of equities is a problem removed from that of maximum well rate limitation for reduction of underground waste.

Sun implied that well rate restrictions solve problems of lease boundary drainage.

Whitehall suggested that maximum permissive rates are implemented partly to prevent inequities.

Pan American contended that lease boundary restrictions were satisfactorily considered in procedures for determining lease allowables and believed that additional restrictions are unnecessary.

Triad, although opposed to general limitations, favoured well rate restrictions for lease boundary wells.

In apparent agreement with Hudson's Bay and Pan American, Imperial suggested that it is the purpose of the GOR, WOR, target area and lease boundary control regulations to maintain equities. In particular, the company stated that GOR penalties were instituted not to control withdrawals for conservation purposes, but to preserve equities among wells in a pool. Imperial expressed the opinion that in any case, recommendations concerning control wells are not a proper matter for consideration for this review since they are not related to prevention of waste, and reiterated that procedures for restriction of control wells already exist.

Texaco Exploration agreed in general with Imperial.

British American also rejected the concept of control wells being assigned special status in a consideration of maximum rate restrictions.

(2) Views of the Board

The Board appreciates the concern of companies both for protection of correlative rights and avoidance of possible damage by improper operation of offsetting wells.

With respect to the correlative rights matter under conditions not involving loss of recovery from the pool, the Board believes that situations which may be prejudicial to such rights would be controlled by the proration allowables, the rules for the formation of PSU's and the application of GOR and WOR penalties. In any case, having announced that the subject of the hearing was the limitation of rates for the prevention of waste, rather than the protection of correlative rights of owners, the need for control well restrictions in this context is not a matter for consideration at this review.

With regard to reservoir damage to offsetting properties, the Board considers that a well could hardly cause underground damage to adjacent properties without first damaging its immediate surroundings. At this stage, the well's rate would in all probability be already limited by gas-oil ratio or water-oil ratio penalties. Moreover, the Board expects that the extent of such damage would be largely dependent upon the relation between total fluid influx or injection and production, and the pressure resulting in various parts of the reservoir. These factors for the most part would be controlled through the setting, when necessary, of an MRL for the pool or a portion of it. In extreme cases individual well MRL's may be required, but this would not depend on whether or not the wells are control wells.

Relationship of GOR and WOR Control to Pool and Well Maximum Rate Limitation

(1) Views of Industry

In testimony at the hearing, gas-oil and water-oil ratio control were related to the need for implementation of maximum rate limitation in various ways.

Imperial stated that gas-oil ratio control becomes significant in limiting individual well rates when GOR differences develop among wells in a pool.

Hudson's Bay submitted that gas-oil ratio penalties together with proration allowables adequately eliminate rates detrimental to any reservoir or well.

Pan American appeared to agree with Hudson's Bay, and emphasized that individual well production rate restrictions enforced by GOR and WOR penalties, together with lease boundary control, are sufficient limitations.

Amerada, while opposing maximum rate restrictions in solution gas drive reservoirs, advocated continued application of gas-oil and water-oil ratio controls.

British American inferred that gas-oil and water-oil ratio controls are sufficiently strong incentives for good conservation practices.

Triad inferred that production at high gas-oil ratio did not necessarily result in permanent damage.

(2) Views of the Board

The Board believes that GOR and WOR controls further production of oil with reduced amounts of gas and water and promote efficient utilization of reservoir energy, but it does not believe that GOR and WOR controls are sufficient to replace pool or individual well MRL's.

Depending upon relative permeability characteristics and gas saturation variations, GOR control can effect conservation by restricting production from areas or zones of relatively high gas saturation and permitting time for saturation redistribution.

Excessive production of water can impair the sweep efficiency of the displacement process and lead to loss of recovery from the pool. Prevention of ineffective use of existing water as an oil recovery agent is an essential measure in the conservation of oil. WOR control helps to conserve water at its proper positions in the reservoir and therefore aids in the prevention of irregular fluid interfaces and undesirable reservoir pressure drop.

The Board agrees with Imperial that GOR control, and in addition WOR control, are principally effective when differences among wells develop in gas-oil and water-oil ratios within a pool. The application of GOR and WOR control affects only the extent of coning that already exists, but the provision of such penalties acts as a deterrent to production practices which could lead to coning. In this way, GOR and WOR control supplements maximum rate limitations.

IV PRESENT PRACTICE OF MAXIMUM OIL PRODUCTION RATE LIMITATION

Introduction

Prior to the discovery of the Leduc oil field in 1947, the Board exercised maximum rate limitation on oil production on a daily basis in the Turner Valley oil field, but in small fields elsewhere in the Province, rather than instituting formal restrictions, it required operators to produce in accordance with good production practice. The "allowables" established for wells in the Turner Valley Field were for the dual purpose of ensuring that production rates were not so high as to cause waste and of serving correlative rights. Following the discovery of Leduc and until September, 1950, maximum rate limitation was imposed in the interest of prevention of waste in the Leduc, Redwater and other newly discovered pools, the rates being determined in the case of each pool on a separate consideration of the reservoir characteristics and the productivity of the average wells.

In September, 1950, the Board established a systematic method of maximum rate limiation which it applied to all pools except Turner Valley and the pools which formerly had been produced under good production practice. The method was expressed in a formula for the calculation of the "maximum permissible rate" (MPR) of production of an individual well. The MPR formula, as it was called, was devised by the Board for the purpose of setting maximum individual well rates early in the life of a pool on a consistent basis and having regard to sound reservoir engineering principles.

It took account of well spacing; pool average values of pay thickness, porosity, connate water and reservoir fluid shrinkage factor; degree of development of the reservoir; and in a general way the nature of the reservoir drive mechanism, the expected recovery and the minimum producing life under good engineering practice.

In essence the formula was a volumetric one, expressing the MPR as ultimate, or initial recoverable, reserves for an average well divided by an appropriate producing life. It is to be noted that the original intent was that the MPR formula would be used only until accumulated knowledge of a reservoir would permit the determination of its true "maximum efficient rate" (MER) through a thorough understanding of the pool recovery process.

The factor relating to the degree of development of the pool was removed from the MPR formula in two steps on May 1, 1958, and May 1, 1959. The form but not the content of the MPR formula was changed in 1960 by expressing ultimate reserves and producing life in explicit form. Also in 1960 the Board clarified its views on well productivity in relation to the MPR. The productivity requirement it adopted specified that the MPR for a well in a pool be not greater than eighty per cent of the estimated current productivity of an average well in the pool.

Documents published by the Board giving details of the MPR formula at the time of its adoption, amendments to it, its modified form, and clarification of the MPR in relation to productivity are reproduced in Appendix A to this report.

The MPR determination by formula with the individual factors established following discussion with industry served as the limitation on a daily basis of the production rate for oil wells until, in December, 1950, the Board at the request of industry, instituted a plan for proration of oil to market demand. The MPR became one factor in determining the average daily allowable set under the proration plan and, in addition continued to play a major role in the determination of the maximum daily rate of production of individual wells. Inasmuch as the proration plan provided for a minimum rate or "economic allowance" for all wells regardless of MPR, in those cases where the calculated MPR was less than the economic allowance, the MPR lost its significance. The MPR has continued to be a factor in the proration plan since inception and will remain so until April 30, 1965.

The foregoing refers to the setting of MPR's for individual wells. In certain cases pool MER's or pool MPR's have been set and here the Board has calculated the equivalent individual well MPR as the pool MER or MPR divided by the number of capable wells. Where pool MER's or MPR's have not been set, the maximum oil production rate from pools has been limited only through the summation of the individual well rate limitations.

Recognizing the need for flexibility in production operations, the Board has provided in its monthly proration orders that individual wells could produce at maximum daily rates which are equal to the greatest of 50 barrels per day, approximately 1.25

times the average daily allowable or the MPR.

From this it is seen that four distinct methods related to the limitation of maximum oil production rate have developed. These are all in effect at the present time. Further elaboration on the way in which these rate limitations are currently established and employed on both a well and pool basis follows.

Details of Present Methods

Good Production Practice. A few pools, most of them in the heavy crude oil category and none subject to proration, are operated under "good production practice". Generally speaking, the requirement of "good production practice" has been applied only to pools of relatively low productivity discovered prior to Leduc. Where there is this requirement, it is the responsibility of an operator to produce his wells in such a manner that underground waste will not occur and an MRL is not prescribed by the Board.

Turner Valley Field - Brown Plan. A variety of methods of maximum rate limitation were applied in the first few years of oil production in the Turner Valley Field. In 1942 the so-called "Brown Plan" was introduced. It provides for maximum daily rates of withdrawal of 25 barrels of reservoir fluid per acre per day, measured at reservoir temperature and pressure, and is applicable to all wells in the field whether producing in the gas cap or the oil zone. Maximum rate limits under the Brown Plan were administered for the first year of its application on a daily basis, in the subsequent ten-year period on a monthly basis, and since then on an annual basis. (The principle of equalization of reservoir voidage developed in the Brown Plan subsequently has been extended in the form of gas-oil ratio penalties to other oil fields in the Province.)

Maximum Rate Limitation through the Greatest of 50 Barrels per Day, 1.25 x the Average Daily Allowable or the MPR. Maximum rate limitation on a daily basis for wells operated on an individual basis, and for units and projects in all designated oil pools except Turner Valley and those under good production practice, is prescribed in the Board's proration order. For wells operated on an individual basis, the limitation in barrels per day is the greatest of 50, the average daily allowable multiplied by 1.25 or the calculated MPR.

For wells operated on an individual basis in oil pools which are not designated or are designated only on account of their inclusion in gas fields, MRL's are prescribed in individual letters to operators rather than being shown in the Board's proration order. In these instances the procedure for establishing MRL's is comparable to that for wells in designated oil pools, except that the lowest MRL is 75 instead of 50 and the calculated MPR is determined on the basis of the characteristics of the individual well affected.

The MRL for a unit, portion of a pool under fully effective enhanced recovery, or an entire pool is equal to the sum of the MRL's of the individual wells involved. In all units and in portions of pools under fully effective enhanced recovery schemes, however, only lease boundary or control wells continue to be subject to the individual well MRL.

Penalties for excess gas and excess water production for individual wells, units or projects are not applied against the MRL.

Pool MER and Pool MPR. The "maximum efficient rate" (MER) of production is that rate of oil production for a particular pool which if exceeded would lead to economically avoidable underground waste and thereby loss of ultimate oil recovery. The MER depends on recovery mechanism, physical characteristics of the reservoir, nature of the reservoir fluids and degree of depletion. The MER is determinable only after a significant amount of production experience and detailed reservoir engineering analysis.

MER's have been established by the Board for a few major pools including Bonnie Glen D-3 A Pool, Fenn-Big Valley D-2 Pool, Redwater D-3 Pool, Stettler Main D-3 Pool, Wizard Lake D-3 A Pool and Westerose D-3 Pool. For a pool with an MER established, provided it is not subject to unit operation, the MRL on a well basis is prescribed in the proration order and is calculated by dividing the MER by the number of capable wells in the pool.

In each of several mature pools subject to satisfactory drive mechanism a pool MPR has been established by the Board as an approximation to the pool MER. In these cases also the MRL for individual wells is determined by dividing the pool MPR by the number of capable wells.

Deficiencies in the Present Methods

During the hearing representatives of industry made reference to a number of deficiencies which they saw in the present methods of establishing MRL's for individual wells, portions of pools and entire pools. The major deficiencies seen by industry and the views of the Board thereon are discussed in the following. In addition certain other deficiencies seen by the Board itself are commented upon.

1. Multiplicity of Methods

(1) Views of Industry

Industry did not comment on the multiplicity of methods currently employed by the Board for the setting of MRL's but confined its criticism to the method most widely used, i.e. the setting of MRL's through the MPR formula.

(2) Views of the Board

The Board does not think it suitable that methods so various as now employed should be used for setting MRL's. It believes as mentioned earlier that to the extent that MRL's may be necessary for individual wells, portions of pools or entire pools, there should be a common policy based upon sound engineering considerations and clearly aimed at the prevention of underground waste.

The Board does not believe that arbitrary limits such as 50 barrels per day, 75 barrels per day or 1.25 times the average daily allowable conform to such a policy. The Brown Plan employed in Turner Valley was designed for the dual purpose of prevention of underground waste and protection of correlative rights. With the substantial pressure depletion of the pool, widespread unit operations and the institution of enhanced recovery operations, its significance as a means of preventing underground waste has been all but lost.

2. Applicability of Maximum Rate Limitations to Individual Wells, Portions of Pools or Entire Pools

(1) Views of Industry

Hudson's Bay, Imperial, Socony Mobil, Sun, Amerada, British American, Shell, Texaco Exploration and Triad, all expressed criticism of the Board's present practice of applying MRL's on an individual well basis, contending, as has been mentioned in Section III, that there is no general need for such limitation for the prevention of waste.

Imperial indicated that present limitation (through the total of individual well MRL's, pool MER's or pool MPR's) on a pool-wide basis or for portions of a pool was not always adequate and that fundamentally limitation should be on a "drainable area" basis. In this concept Imperial received only partial endorsation from other companies. Particularly in reference to pattern flood schemes, others considered the application of the drainable area concept as being unnecessary.

(2) Views of the Board

With respect to the applicability of MRL's to individual wells, the Board agrees with the majority of industry that the present methods result in the fixing of such MRL's even where they do not appear necessary for the prevention of waste.

The Board also recognizes the validity of the criticism that the present method with respect to portions of pools and entire pools gives insufficient recognition to the portions of pools which may behave separately from one another and, through both the average well concept and the application of the MRL on a pool-wide basis or even to portions of a pool, inadequate limitation may result in some portions of pools while unnecessary limitation may be imposed on others. This does not apply however in cases where pool MER's have been established nor fully in cases where pool MPR's have been established.

3. The MPR Formula as a Method of Calculating MRL's for Wells, Pools and Portions of Pools

(1) Views of Industry

Most of those making submissions at the hearing made it clear one way or another that they did not believe the MPR formula was a suitable framework for the determination of MRL's, even conceding their need. Particularly definite in this view were Imperial and Socony Mobil.

The industry criticism was directed chiefly to the role of the MPR formula in determining the MRL for a pool or a portion thereof, whether by the aggregating of individual well MPR's or otherwise.

Imperial stated in its submission that the MPR formula, while meant only as an interim "hand rail to judgement", had tended to supplant the basic MER concept. It contended moreover that well factors were introduced which undermined the technical significance of the MPR formula and left it solely as a market sharing device. In a similar vein, Socony Mobil expressed the belief that as a result of the dual use of the MPR, in the proration plan and in limiting production rates to avoid waste, the MRL as presently determined from the MPR formula is not a realistic maximum rate necessary to avoid waste. California Standard, Dome, Home, Pacific and Shell supported one or another of these viewpoints.

(2) Views of the Board

The Board agrees with Imperial that the MPR formula was intended as "a hand rail to judgement" and not as a substitute for detailed individual pool MER studies. The intended function of the MPR formula is made clear in the documents in Appendix A. The Board does not understand the criticism that the MPR formula has tended to supplant the MER concept, unless the suggestion is that the MPR formula often has resulted in a pool MRL close to or even greater than would have been indicated by an MER study and, therefore, that operators have not pursued such studies. Certainly the Board has given great weight to all detailed MER studies it has received.

Imperial's reference to the undermining of the technical significance of the MPR formula through the introduction of well factors is taken to be a reference to the "life factor" (related to well spacing, pool average permeability, pay thickness, etc.) and perhaps also to the arbitrary limiting of the MPR to eighty per cent of the demonstrated average well productivity. Socony Mobil's comments to the effect that the

MRL determined by the MPR formula is not realistic appear related.

The Board has reviewed the MPR formula and the way in which it is employed from the point of view of the objectives of maximum rate limitation in general and having in mind the many possible causes and sources of the underground waste to be prevented. While basically the formula is a simple expression of the ratio of ultimate reserves to producing life, the estimation of the recovery factor and particularly of the producing life is difficult. Through the incorporation of pool average ultimate reserves per spacing unit, the Board believes the formula is in this respect properly related to overall pool recovery. On the other hand, the estimation of a producing life, which should have regard for factors affecting both reservoir drive mechanism and the rate and time of movement of reservoir fluids to the well bore, has in practice been thought of more in terms of well spacing and typical well performance than of overall reservoir performance.

One way of considering the formula is to recognize that it represents an attempt to combine in a single simple statement the factors which might most affect a "reservoir" MER and those which would appear most significant in determining an "individual well" MER. The Board recognizes the difficulties inherent in arriving at a proper such combination and the fact that the MPR formula has shortcomings in this respect. As applied to pools of excellent reservoir characteristics the formula yields a pool MRL virtually independent of spacing and comparable to that indicated by segment AB in Figure 1. This result is proper because for such pools the true pool MER would be the "reservoir" MER within the practical range of oil well spacing. On the other hand, when the formula is applied to pools of poor reservoir characteristics it yields a pool MRL which is nearly inversely proportional to well spacing as indicated by line DBE of Figure 1. The result may be satisfactory within the spacing range corresponding with segment BE but would exceed the "reservoir" MER at closer spacing - as along segment DB.

A further shortcoming of the formula is that pool depletion effects may not adequately be recognized since they are accounted for only indirectly through the producing life.

In the case of enhanced recovery schemes the MER or its equivalent cannot be determined by any general formula, including the MPR formula, based solely on reservoir and related factors. This is because such enhanced recovery schemes are designed to overcome the restrictions of natural reservoir factors and to permit production at forecast rates. Frequently a high degree of artificial control may thereby result. The optimum producing rate depends to a large extent on factors such as the number and location of injection wells and the kinds of fluid injected and is determined by the design of the scheme and the realization of its objectives.

4. Period of Applicability of Maximum Rate Limitations

(1) Views of Industry

Nearly all companies making submissions indicated that the present application of MRL's on a daily basis, as distinct from a longer period, was unnecessary in the interest of conservation. Their contention was that production at high rates would have to continue over months or perhaps years before underground waste would occur. Whitehall alone expressed the contrary view that serious reservoir damage could take place in a period of time as short as a day.

(2) Views of the Board

In those cases where the sum of "individual well" MER's exceed the "reservoir" MER, the Board agrees that the pool MRL need not be set on a daily basis and that the present daily basis is unnecessarily restrictive. On the other hand, where the sum of "individual well" MER's may control the true pool MER, the Board does not agree that the daily basis is necessarily unsuitable. The Board believes that where gas or water coning and other phenomena related to well bore drawdown may cause waste, their proper control may require individual well MRL's on a daily basis.

V SPECIFIC PROPOSALS REGARDING MAXIMUM RATE LIMITATION

Pool Rate Limitation

(1) Views of Industry

Maximum rate restrictions to pools or parts of pools were supported in general by Imperial, Amerada, British American, California Standard, Dome, Pacific, Pan American and Shell.

Imperial stated that MER's should serve as the basis for maximum rate control, but that, as MER's are not determinable early in the life of a pool, a safe maximum rate should be set to apply until MER studies are feasible.

It suggested further that any maximum rate was significant only if utilized for a particular drainable area defined by natural or artificial boundaries, which may comprise all or part of a pool. It said that within each drainable area recovery would be insensitive to the number of wells, and reservoir factors governing performance might be averaged for the drainable area.

Imperial recommended an arbitrary maximum monthly rate (MMR) for each drainable area, of 9000 barrels per month per million barrels of proratable reserves, where proratable reserves are the reserves attributed to the drainable area under the new proration plan and are equal to ultimate reserves of the drainable area less half its cumulative production. The formula recommended was:

$MMR = 9000 \times 10^{-6} (U - P/2)_{DA}$ in stock tank bbl/month,

where U is the ultimate recoverable reserves in stock tank bbl,

P is the cumulative production in stock tank bbl, and

DA refers the values to the drainable area.

Imperial also said that under the drainable area concept, individual five- and nine-spot patterns within a project would be separate drainable areas, but that for peripheral floods the entire area within the peripheral flood would be a drainable area, in the absence of significant distinguishing features.

Imperial contended in its submission that its proposed MMR formula gave maximum rates which were suitable. In particular it stated that experience in the United States with high production rates and studies of the effect of rate on recovery, though giving a wide range of results, indicates that the range in the estimates of safe percentage depletion rates per year mostly fall between 5 and 15 per cent of ultimate reserves.

It added that in Alberta MER studies have been reported for a number of major pools and several smaller pools and that these indicate that, depending on the pool, sustained rates within the range of 8 to 12 per cent depletion per year should not cause reservoir damage or waste. In comparison the percentage depletion rates per year in terms of ultimate reserves permitted through application of Imperial's MMR formula commence at a rate of 10.8 per cent, decline to a terminal rate of 5.4 per cent and average about 8 per cent over the pool life.

Imperial submitted that the formula gives a minimum reserve-life of about 13 years in comparison with the life for a well in a 40-acre spaced pool of about 10 years provided by the Alberta MPR formula. Imperial said that by this comparison (for pools on 40-acre spacing) the Imperial MMR proposal gives rates which are generally conservative, particularly at advanced stages of depletion. A Board staff comparison of corresponding MMR's and MPR's submitted by Imperial indicated that on the average the pool MMR was 95 per cent of the pool MPR.

To avoid arbitrary application of MMR's to individual wells during the early life of a pool when drainable areas may not be readily defined, Imperial proposed that no maximum rate limitation be applied until two years after pool designation. It submitted that this procedure should be satisfactory because the instantaneous MER is generally highest during this early period.

Imperial further submitted that no MMR's should be assigned to solution gas drive drainable areas because their ultimate recovery is characteristically not rate sensitive. A similar view was expressed by Amerada, Dome, CPOG, Pan American and Shell.

Imperial further proposed that, where the formula gave a rate which was less than the minimum allowance rate provided under the proration plan, the minimum allowance would apply. This proposal was supported by British American. Imperial added that it would be unnecessary to adjust the minimum rate upwards to provide flexibility in daily operation if the minimum well allowance were also applied on a monthly basis.

Imperial stated, in reply to a question by Husky, that it had not tested the applicability of its MMR formula to pools of the Lloydminster type producing heavy crude oil. It added, however, that the formula should be applied to all types of pools not excluded by the provisions of its proposal.

Imperial submitted that the proposed MMR formula should be applied on a drainable area basis and that it would provide maximum rates which

(a) would preclude the possibility of waste in reservoirs of widely different types at various stages of depletion,

(b) should be high enough so as not to encourage unnecessary or premature MER studies,

(c) should not arbitrarily inhibit operating efficiencies where conservation is not affected, and

(d) should have technical and administrative simplicity and require only such data as are commonly available.

As discussed in Section III, Imperial expressed the belief that, because of the difficulty of determining the MER, particularly early in the pool life, the MMR proposed was appropriate as an interim MRL. Further, for reasons discussed in Section III, it did not believe a daily rate limitation to be necessary.

None of the companies supporting maximum rate limitations agreed completely with Imperial's concept of drainable areas. British American said that pools should be divided for MMR purposes only in accord with obvious and major differences in reservoir characteristics. Pacific and Pan American proposed that separate maximum rate restrictions be assigned on the basis of proratable reserves for areas of a pool subject to a particular type of recovery mechanism such as waterflood. The maximum rate limitation for the mechanism would then be apportioned on an area basis to areas of common ownership. Pan American and Dome both said that the areas recognized for the application of MMR's should be the same as areas within a pool recognized in applying the new proration plan. Hudson's Bay took the same argument further, contending that the drainable area concept not only deviated from the new proration system, but to some extent substituted proration on the basis of drainable areas for proration on the basis of area modified by recovery factor.

Imperial in rebuttal stated that it was reasonable that the drainable area concept should deviate from the concept of pool proration. It added that the two concepts were unrelated with pool proration being for the purpose of giving each well owner the opportunity of producing his just and equitable share of the oil in the pool and maximum rate control being concerned with prevention of waste. While agreeing that maximum rate restrictions can affect proration, as Hudson's Bay contended, it expressed the belief that this was proper since proration considerations should be subordinate to conservation.

Shell took the position that the imposition of a maximum rate for individual patterns in any pressure maintenance scheme would be a superfluous restriction that would add administrative complexity without aiding the overall objective of eliminating waste and reservoir damage. It submitted that the MMR in any pressure maintenance scheme should pertain to the project or unit area as a whole. In addition Shell did not support Imperial's proposal that an MMR should not be applied during the two years immediately following pool designation. Shell submitted that in a small pool damage could occur in the first two years as well as later.

Hudson's Bay, as mentioned in Section III, expressed the belief that proration allowables would continue to be sufficiently low for many years to render MRL's unnecessary.

Socony Mobil took a position similar to that of Hudson's Bay in that it recommended that each pool or portion thereof be permitted to produce without any maximum rate limitation until there is sufficient evidence that the rates being used will be detrimental to the reservoir. It stressed that its proposal was preventative in nature in that it provided for application of maximum rate limitations where there was evidence of potential waste occurrence. Socony Mobil suggested that the necessity for a restricted production rate can be reviewed as part of the periodic reserve determination for each pool. It believed that sufficient prior evidence that a rate was detrimental to a pool would be provided by GOR's, WOR's and reservoir pressure distribution data. Socony Mobil and Great Plains argued also that MRL's should be studied separately considering relevant pool performance characteristics rather than being subjected to an MRL derived from a general formula. Socony Mobil argued further that use of a general MRL formula to establish a maximum rate for a pool might in some cases result in an unjustifiable production penalty or restriction where the proration allowable granted to a drainable area is higher than the arbitrary MRL. It added that there may be no technical argument for relief from such an MRL, which itself has no technical justification for its original imposition. Moreover, the lack of technical justification might render contestable the validity of such a Board order. In addition, Socony Mobil submitted that the establishment of an MRL such as that proposed by Imperial would in no way eliminate the need for a continued surveillance by the Board of the performance of pools within the Province, with a view to obtaining assurance that waste was not occurring.

Sun, Home, Great Plains, Texaco Exploration and Triad supported Socony Mobil's views in general.

Whitehall, taking a different position, expressed the belief that both daily and monthly rates of production should be restricted in some instances but it appears its comments respecting daily rates were intended to apply to individual well limitations. Whitehall contended that short-term high rates of production could cause undue reservoir damage, and that daily maximum rates, where such rates are necessary, should be limited to about 10 per cent of the monthly allowables. It felt that restrictions on monthly rates of withdrawal were necessary largely for what it called equity reasons.

California Standard suggested that the maximum rate limitation be set at not less than twice the monthly proration allowable rate to allow appropriate flexibility to accomodate reworks and other production difficulties. Upon being questioned by Socony Mobil, however, it agreed that greater flexibility in carrying forward under-production would probably accomodate these problems without requiring a greater maximum rate flexibility.

California Standard added, on being questioned respecting maximum rate limitations for unprorated pools, that the MPR may provide a satisfactory maximum rate limitation in unprorated pools such as those at Bantry which are not presently permitted to operate on a good engineering practice basis.

Hudson's Bay, Imperial, Pacific and Pan American either stated or implied that if MRL's are applied on a pool or pool segment basis in areas where the ownership is not the same the MRL should be divided among the holdings on an area basis.

(2) Views of the Board

The Board, as stated in Section III, agrees with those who submitted that generally it is necessary to keep pool performance under careful surveillance. It further agrees that it should apply maximum rate limitations to pools and distinct parts of pools where following careful study such limitations appear necessary for the prevention of waste.

In pools where maximum efficient rates can be established, these rates should be determined as soon as reasonably possible and should control the maximum rate of depletion of the pool. The Board, like Shell, does not concur with those who would in all cases defer application of maximum rates of production to drainable areas until two years after the pool is first designated.

Respecting the need for maximum rate limitations for solution gas drive pools or pool segments, contrary to the views submitted by some companies the Board believes such limitations are desirable for the reasons and in the circumstances referred to in Section III. Further the Board believes that the drive mechanism in pools is seldom entirely solution gas drive even though that mechanism may be dominant and, in addition, the drive mechanism frequently cannot be immediately identified. It therefore believes that any pool or pool segment even though it may appear to be producing by solution gas drive should be kept under surveillance respecting the need for rate limitation.

The Board as mentioned previously does not agree with California Standard that relating the MRL to the proration allowable is a satisfactory method of limitation nor that the existing MPR's would serve as MRL's where rate limitation was necessary for unprorated pools. The Board's reasons in this respect are given in Sections III and IV.

With respect to the period over which pool rate limitations would apply, the Board agrees with the majority of those making submissions that daily maximum rate limitations in pools or pool segments are not necessary and that where limitations are required suitable maximum monthly rate limitations fulfil the objectives.

The Board also agrees with Imperial, British American and Hudson's Bay that the MRL of a pool should not be less than the sum of the minimum allowances of the wells in the pool. The Board believes, however, that since the minimum allowance, particularly at the level which will come into effect May 1, 1969, is intended as a minimum economic rate it would be desirable to permit operators some flexibility in producing the minimum allowance. In addition it does not agree with Imperial that adequate flexibility is in all cases provided by a monthly allowable. The Board therefore believes that, in the case of prorated pools, the maximum rate limitation should be not less than 110 per cent of the sum of the lesser for each well of the minimum allowance or the productivity. It further believes that, in the case of unprorated pools, the minimum level of the pool MRL should be determined having regard to production economics and necessary flexibility.

The Board sees some merit in the Imperial proposal for establishment by a general formula of MMR's for drainable areas and agrees that it requires only such data as are commonly available, that it has technical and administrative simplicity and that its use would not encourage unnecessary or premature MER studies. It agrees with Socony Mobil and Great Plains, however, that use of one general formula even to establish tentative maximum rates for a wide variety of pools subject to various drive mechanisms or combinations of drive mechanisms is not satisfactory since it could result in unnecessary or improper rate limitation in individual cases. By Imperial's evidence from its investigations the range of the values in the maximum efficient rate of depletion of ultimate reserves is from some 5 to 15 per cent per year. This would lead to a range of values for the constant in Imperial's MMR formula of 5000 to 16,000 x 10^{-6}. Further in the Board's view, even in the early stages of depletion of a pool, more discretion that would be exercised through use of a formula dependent only on reserves as proposed by Imperial is warranted in setting a maximum rate limit. While it does not appear desirable to adopt the Imperial proposal fully the Board believes the concept could be used beneficially in a maximum rate limitation policy.

The Board has studied the range of values of K in the Imperial formula that could yield maximum rate limits that it thinks appropriate for a cross-section comprising some forty pools in the Province. The Board has found on the basis of this study, that the value of K would range from about 6,000 x 10^{-6} to about 12,000 x 10^{-6}, averaging about 9,000 x 10^{-6} confirming Imperial's figure as a suitable average. The Board therefore proposes to adopt the Imperial formula in the form "$PRL = K \times 10^{-6}(U - P/2)$" as a surveillance device to provide preliminary rate limitations (PRL's) wherein K would normally have a value of 9,000. The PRL would be established in barrels per month. A value of K of 7,000 or 11,000 would be employed where, in the Board's view, on the basis of a pool's characteristics and recovery mechanism, the particular value appears more appropriate. The Board staff would determine a PRL for each pool or separable portion for which an MRL has not, following an MER or equivalent study including a study leading to the approval of an enhanced recovery operation, been established or recognized by the Board. When it appeared that the production from a pool might soon approach the PRL the operators in the pool would be asked to make an MER or equivalent study and submit it to the Board for consideration, possibly at a public hearing. Following consideration of the submission the Board would determine the need for an MRL, and if necessary, set one. Where MRL's are not set PRL's would also be utilized by the Board in estimating the crude oil productivity of the Province.

Respecting the extent to which the drainable area concept should be adopted, the Board believes that, in the case of pattern floods, differentiation between areas subject to flood according to the injection fluid utilized is warranted in view of the variation in displacement efficiencies and volumetric sweep efficiencies for the fluids used. It further believes that differentiation between projects in areas of a pool subject to flood by the same fluid is warranted in view of the great extent of the variation in pool characteristics which can exist between projects. On the other hand within a particular project the Board already requires that production be distributed on a pore volume basis, except where another basis of distribution is justified in recognition of stratification, capillary or other effects. Recognizing this requirement, the uncertainties in the determination of the characteristics of the various patterns of a project and the administrative burden of applying maximum rate limitations on a pattern basis, cited by Shell, the Board believes that routine application of an MRL to each pattern of a project is unwarranted. The Board thus agrees with Shell that for pattern floods the PRL or MRL should apply to the full area of each project, rather than to the entire area of the pool subject to flood by the same fluid as proposed by Pacific and Pan American or to each individual pattern as proposed by Imperial.

With respect to PRL's for prorated pools where MRL's have not been established or the equivalent has not been determined in the case of enhanced recovery operations, the Board staff would begin a review of the pools in the Province in May, 1965. Where it appears to the Board to be desirable that an MRL study be made for the pool the operators of the wells would be asked to prepare such a study and submit it to the Board within a suitable period.

In unprorated pools, the Board believes that MRL's are necessary and should be established soon after pool discovery to be utilized with GOR and WOR penalties in maintaining correlative rights as well as in promoting conservation in each pool. However, as stated in Section III the Board believes it should use the same principles in arriving at MRL's for unprorated pools as for prorated pools. For those unprorated pools where GOR and WOR penalties are applied the Board believes PRL's or MRL's should be set to be effective May 1, 1965. These tentative rate limitations would be subject to review.

The Board agrees with Hudson's Bay, Imperial, Pacific and Pan American that in pools and portions of pools that are subject to a common MRL and are competitively operated, the MRL should where necessary be distributed among the various holdings on an area basis.

Individual Well Rate Limitation

(1) Views of Industry

For reasons outlined and discussed in Section III, neither Imperial nor Socony Mobil, nor those companies supporting their submissions, conceded any necessity of maximum rate limitation for individual wells. Hudson's Bay and Triad both expressed the belief that individual well maximum rate limitations would nullify to a significant extent the benefits of flexibility due to production spacing unit and block allowables provided in the new proration plan.

Whitehall made the only submission in favour of individual well maximum production rates. It said that oil recovery could suffer in some pools as the result of high individual well daily production rates and recommended that where there appeared to be a hazard of well damage the daily production from an individual well or PSU not be allowed to exceed perhaps ten per cent of the monthly allowable.

Husky, supported by British American, submitted that pools of the Lloydminster type, producing crude oil having gravities numerically less than 20°API, should be treated in a manner different than light and medium crude oil pools. Husky stated that it was necessary to produce wells in pools of this type at capacity and that the present policy of allowing flush production for limited periods was essential to the economics of primary production. Husky suggested that some restraint on wells may be necessary to avoid damage, as for example, that due to sand sloughing, and recommended a maximum well limit of 50 barrels per day, but preferred the equivalent on a monthly basis. Husky stated that its recommendation was essentially one for good production practice.

Hudson's Bay and Triad said that, although they were generally opposed to well production rate limitations, they did not object to lease boundary control for equity purposes. Triad went further, suggesting a maximum lease boundary well producing rate equal to 1.25 times the allowable of a quarter section or PSU.

(2) Views of the Board

The Board generally concurs with the industry view that ultimate oil recovery is not usually sensitive to individual well rates although in some cases some reduction in recovery may result from unreasonably high well production rates. The Board appreciates that in these cases industry will generally apply good production practices and, that, in fact there are incentives through WOR and GOR penalties and through the proration plan for such practices. However, the Board believes it should have provision for the application of individual well daily or monthly maximum rates where the practice does not appear to be satisfactory and the ultimate oil recovery from the pool may be adversely affected if individual well MRL's are not applied.

The Board believes that the performance of wells in those pools where the ultimate oil recovery from the pool is apt to be dependent on individual well performance should be kept under surveillance. Evidence of the need for individual well maximum rate limitation may be provided by WOR and GOR performance, reservoir characteristics at the well as indicated by core, log and fluid analyses data, and by individual well productivity. Where it appears to the Board that individual well MRL's may be necessary in a pool the Board would request a submission from the operators concerned and following receipt of such a submission consider the evidence at hand possibly following a public hearing. If following this assessment daily or monthly individual well MRL's appear appropriate they would be prescribed. However, the Board does not anticipate that such individual well MRL's would depend upon the area attributed to the well.

The Board believes that this policy is appropriate for both prorated and unprorated pools and expects that the operators will keep these considerations in mind in applying for enlargement of production spacing units.

VI CONTROL OF GAS AND WATER PRODUCTION

Introduction

Although the Board had intended that only one aspect of GOR control be subject to discussion at the hearing, other matters were mentioned in testimony. For this reason and to complete the discussion the Board believes it appropriate to review broadly GOR and WOR control in the Province relevant to maximum rate limitations.

Gas-Oil Ratios

The Board policy respecting the control of gas production in oil pools has evolved from representations from industry and the Board's interpretation of its responsibilities under The Oil and Gas Conservation Act. Some purposes of the Act are to afford each owner the opportunity of obtaining his just and equitable share of production and to prevent waste.

Gas production was taken into account in establishing allowables in the Turner Valley Rundle Pool through the Brown Plan described in Section IV. Later in the D-2 and D-3 pools in the Leduc Field soon after discovery the Board set gas allowables at 1000 cubic feet per barrel of liquid production allowable.

Following this a general policy was gradually developed of providing, more or less, equivalent total fluid withdrawals from a reservoir at wells producing at various gas-oil ratios but allowing proper operating flexibility. The policy provided for penalty factors on allowables of individual wells producing at excessive gas-oil ratios. To account for differences in separator pressure and the relationship between separator pressure and GOR, penalty factors were related to both of these variables. Separate tabulations of penalty factors for different GOR's were developed for each of several critical GOR's giving the penalty factor as a function of the sum of separator pressure and the producing gas-oil ratio. The critical GOR was initially taken as twice the pool average solution GOR, but after about 1958 a value of roughly 1.5 times the average solution GOR was used. This level of 1.5 times the solution GOR was believed sufficient to provide reasonable operating flexibility. However, for GOR's significantly greater than 1000 cubic feet per barrel, the 1.5 factor is gradually reduced so that no more than reasonable operating flexibility is provided.

The penalty factors are developed according to the following relationship:

$$\text{Penalty factor} = \frac{\text{Pool Average Critical GOR}}{\text{Separator GOR + Separator Pressure}}$$

Tables have been established for critical GOR's of 200 to 5000 cubic feet per barrel but tables for critical GOR's below 1000 have not been applied except in special circumstances described later. The penalty factors are rounded to two significant figures. A set of the tables is set out in the First Schedule to the General Regulations under The Oil and Gas Conservation Act and is reproduced in Appendix B to this report.

In solution gas drive, gas cap expansion and combination drive pools in advanced stages of depletion where an enhanced recovery scheme is not feasible and where more than half the wells are significantly penalized for GOR, the Board has reduced penalties by applying a penalty table corresponding to a higher critical GOR, or, in special cases, exempted the pool from GOR penalties.

Where gas is gathered and returned to the pool, GOR penalties are calculated on a "net GOR" basis, where returned gas is deducted from gas produced. Similarly, where gas production is substantial and is marketed, the pool may be assigned a gas allowable and granted relief or exemption from penalties respecting the oil allowable. The table to which the net gas-oil ratios are to be applied in determining the allowable reduction factors is selected on the basis of the lease fuel requirements and may be one of the tables established for critical GOR's below 1000 cubic feet per barrel.

In the Lloydminster Mannville pools gas production has been restricted on the basis of Schedule C of the First Schedule to the General Regulations under The Oil and Gas Conservation Act. This schedule, shown in Appendix B to this report, permits the production from each well of a volume of gas dependent upon the area assignment and oil production rate.

Other methods for controlling gas production have been used for a time in a few pools where the pool is subject to concurrent gas cap and oil zone depletion, but these have now been discontinued.

Water-Oil Ratios

The Board policy respecting control of water production, like that for control of gas production, has evolved from representations from industry and the Board's interpretation of its responsibilities under The Oil and Gas Conservation Act.

Individual well allowable producing rates in Alberta were first modified for water production during the development of the Leduc Field. The initial water-oil ratio penalty formula reduced the oil allowable one barrel for each barrel of water production and was expressed as:

$$\text{Penalty factor} = \frac{1}{1 + \text{WOR}}$$

After some experience the suitability of this formula was reviewed and in 1950 the following formula, which for most pools is still in effect and provides a penalty about half that provided by the previous formula, was adopted:

$$\text{Penalty factor} = \frac{2}{2 + \text{WOR}}$$

The penalty factors given by the formula rounded to two significant figures are set out in Table 0.0 of Schedule B to the First Schedule of the General Regulations under The Oil and Gas Conservation Act, shown in Appendix B to this report. It will be noted that no penalty is prescribed for water-oil ratios below 0.0200.

In 1960, following consultation with the Canadian Petroleum Association and the hearing in April, 1959, by examiners appointed by the Board of an application by the operators in the Malmo Field and New Norway Field, the Board modified the penalty factor formula for pools having effective water drives to:

$$\text{Penalty factor} = \frac{2}{2 + \text{WOR}\ (1 - \text{WDI})}$$

where WDI is the water drive index, the ratio of the net water influx into the pool to the net reservoir volume of oil and gas produced. Following this, Schedule B of the First Schedule to the General Regulations under The Oil and Gas Conservation Act was amended to include tables of water-oil ratio penalty factors for water drive indices of 0.7, 0.8 and 0.9. The Board stated it would consider an application from the operators of wells in each pool having a water drive index equal to or greater than 0.7 for assignment of the appropriate of these less restrictive tables.

As in the case of GOR penalties, WOR penalties are assigned on a net WOR basis where water is returned to the pool of origin, or to other pools with a common aquifer in good communication with the pool of origin.

The WOR penalty tables are reproduced in Appendix B to this report.

Modifications Proposed by Board Staff to GOR Penalty Base

The Board staff made a submission recommending changes in the penalty base for the calculation of gas-oil ratio penalty tables under Schedule A. It recommended that gas production of 0.5 reservoir barrels per stock tank barrel of oil produced in addition to the solution GOR, rather than gas production of 1.5 times the solution GOR as under the present system, be allowed penalty free. Under the proposal, the gas penalty table would be determined by

(a) estimating the bubble point pressure of the crude oil,

(b) estimating the reservoir temperature,

(c) determining the gas formation volume factor for the temperature and pressure using the formula:

$$V = 4.264 \frac{T}{P}$$

where V = the gas formation volume factor, $\frac{\text{reservoir bbl}}{\text{Mcf}}$

4.264 = the constant corresponding to a pressure base of 14.65 psia, a temperature base of 60 F, 5.615 cu ft per bbl and a gas compressibility factor tentatively taken as 0.85,

T = reservoir temperature, R

P = bubble point pressure, psia,

(d) determining the volume in standard cubic feet of the free gas in 0.5 barrels of reservoir space and adding this to the initial solution gas-oil ratio in cubic feet per barrel to obtain the critical GOR, and

(e) selecting the gas-oil ratio penalty table (assigned critical GOR) nearest the calculated critical GOR provided the difference between the average solution GOR and the assigned critical GOR shall in no case be less than 200 cubic feet per barrel.

The advantages claimed for this method were that it provided for the assignment of GOR penalty tables in a consistent manner with appropriate flexibility under all foreseeable reservoir conditions, that the permitted depletion would not be seriously dissimilar to that under the present system, and that the data used involved only factors which would be necessary for other purposes early in the life of the pool.

(1) Views of Industry

Socony Mobil expressed the belief that provision should be made for the GOR penalty base to vary within a pool, and was supported in this view by Dome.

Imperial, in agreement with the Board staff, said that to preserve the underlying principle of GOR penalties, the penalty base should be tied as closely as practical to original solution GOR's. Shell and Pacific supported this view.

California Standard expressed the belief that rather more flexibility than 0.5 reservoir barrels per stock tank barrel of oil produced was necessary in the penalty base. It suggested a formula allowing for each stock tank barrel of oil production one reservoir barrel of gas production in excess of the solution gas, but on being questioned regarding the high levels of GOR possible with such a penalty base, said it was thinking more in terms of 1000 cubic feet of excess gas to provide flexibility. Sun was similarly concerned about the degree of flexibility provided in the penalty base and suggested a base equal to twice the solution GOR.

Dome, although professing no real objection to the Board staff submission, thought it would be equally valid, and simpler, to set the penalty base as some multiple of solution GOR, and suggested it be set at 150 per cent of solution GOR.

Triad thought that the present GOR penalty base was adequate and stated that the Board staff proposal to obtain what was essentially an arbitrary number was unduly complicated. Furthermore, Triad said that as the Board staff submission suggested that the proposed changes would give results not unduly different from those under the present method, it was unnecessary to make revisions. Triad added that though it agreed with present penalty policy, it felt that review was needed with a view to lessening the degree of restriction. On being questioned, Triad said that it did not believe permanent damage would be caused if individual wells were allowed to produce at GOR's of the order of twice the solution GOR.

Husky suggested that for the Lloydminster type pools producing heavy crude oil 30,000 cubic feet of gas per day per well be permitted without penalty. Hudson's Bay thought that Husky's proposal was too restrictive pointing out that on the basis of Husky's suggested maximum well rate of 50 barrels per day, allowing 30,000 cubic feet of gas production without penalty was equivalent to applying Table 600.

Imperial, like Socony Mobil, suggested variations be made to the penalty base for a pool only where significant variations in solution GOR's within the pool occurred.

(2) Views of the Board

The Board believes that the method of selecting the gas-oil ratio penalty table to apply to a pool, proposed by the Board staff, should be implemented May 1, 1965, for pools designated after April 30, 1965, and May 1, 1966, for pools designated before May 1, 1965. In instances where there would be a serious adverse effect on the economics of gas gathering or processing due to change in penalty tables and an operator would suffer hardship thereby, the Board, on application by the operator, will consider extension of the use of the table currently in effect for the pool. Where transfer of economic allowances from injection wells is presently provided for in a pool, the terminal transfer recovery point would be determined as presently prescribed. Where transfer of economic allowances from injection wells becomes warranted during the period prior to May 1, 1968, and the terminal transfer point is not presently prescribed, it would be determined in the case of pools designated prior to May 1, 1965, using the GOR penalty table in effect at April 30, 1965. In the case of pools designated after April 30, 1965, it would be determined using the table in effect at the time the terminal transfer recovery curve for the pool is adopted by the Board.

Respecting the proposal by Socony Mobil and Imperial that provision should be made for variation of the critical GOR within a pool the Board believes that where different critical GOR's are indicated in different parts of a pool the change in fluid characteristics generally occurs gradually from one area to another. From an administrative point of view, abrupt changes in the penalty schedule would be necessary, and changing the penalty schedule within the pool could lead to arbitrary differentiations particularly at the boundary between areas on different schedules. The Board therefore believes that such variations in the critical GOR within a pool should be permitted only in extreme circumstances.

The Board does not agree with Husky that gas production in Lloydminster type pools producing heavy crude oil should be restricted by prescribing 30,000 cubic feet per day of gas production per well nor does it agree that the provisions of Schedule C presently prescribed for the Lloydminster Mannville pools are completely satisfactory. It believes that gas production in all crude oil pools can be satisfactorily controlled using the tables of Schedule A included in Appendix B.

Applicability of Tables 200, 400, 600 and 800

The Board staff suggested in its submission that for a pool where the solution gas-oil ratio and the rules proposed for selecting the allowable reduction factor table indicate that a lower critical GOR than that of Table 1000 should apply, the corresponding table be prescribed if the pool was discovered after May 1, 1965.

(1) Views of Industry

Those from industry commenting on this subject, with the exception of Dome and Triad, were in general agreement that the suggested policy should be followed. California Standard, however, submitted that the tables should apply to all pools.

Dome submitted that, except on a net basis, Tables 200 to 800 should not be implemented, as gas volumes at this level associated with oil production were too low to be measured with any degree of accuracy. Triad took the argument further, submitting that penalties based on gas production in the volume at which the tables would apply was overly restrictive. Furthermore, Triad believed that to apply the tables to new pools only would give old pools operating on Table 1000 a producing advantage.

(2) Views of the Board

The Board concurs with the majority of industry that tables based on critical GOR's below that of Table 1000 should be applied where appropriate, and subject to the following modifications, believes it should adopt the rules proposed by the Board staff.

The Board believes that the subject tables should apply, by the rules proposed by the Board staff, effective May 1, 1965, to pools designated after April 30, 1965, and to all pools as of May 1, 1966, but recognizes there may be instances where there would be a srious adverse effect on the economics of gas gathering or processing due to the change in penalty tables and an operator would suffer hardship thereby. In such cases, on application by the operator, the Board will consider extension of the use of the current table. Where transfer of economic allowances from injection wells becomes warranted during the period prior to May 1, 1968, and the terminal transfer point is not presently prescribed, it would be determined, in the case of pools designated prior to May 1, 1965, using the GOR penalty table in effect at April 30, 1965. In the case of pools designated after April 30, 1965, it would be determined using the table in effect at the time the terminal transfer recovery curve for the pool is adopted by the Board.

The Board agrees with Dome and Triad that at very low rates of gas production difficulties would be experienced in measurement using conventional metering equipment. However, since the rules for selecting penalty tables proposed by the Board staff require that the difference between the solution GOR and the critical GOR be not less than 200 cubic feet per barrel, the lowest penalty table which would be prescribed would be Table 400. Gas volumes which would result in gas-oil ratio penalties with Table 400 and other applicable tables appear to be measurable with satisfactory accuracy.

Credit for Injection of Other Fluids

(1) Views of Industry

Almost without exception, those companies making submissions on this subject said that the applicable GOR penalty should be based on gas produced less the appropriate equivalent volume of fluids injected.

Imperial supported the selective application of GOR penalties on a net basis whereby gross gas production is reduced by the amount of fluid injection on an appropriate equivalent volume basis.

Hudson's Bay stated that the GOR penalty factor should be based on net gas withdrawals allowing credit for all fluids injected anywhere in the lease or block, even though the ratio of injection to production might vary from area to area across the lease or block. It stated in answer to questioning that if in a particular project the injection were so remote from a producing area that the depletion mechanism in that area was inefficient this should be taken into account in the recovery factor utilized rather than in the GOR penalty.

Dome, Pacific, Socony Mobil, Pan American, Great Plains, Texaco Exploration and Skelly all said that, in calculating the GOR penalty, credit should be given for injection of all fluids. Each of these companies, like Hudson's Bay, were questioned by the Board regarding the application of credit for injected fluids in projects where the point of injection in the projects was remote from the well producing excess gas and there was evidence of poor communication. All agreed that the response to injection should be considered and where communication was poor the credit for injected fluids should be modified.

(2) Views of the Board

The Board concurs with the view that normally it is proper to give credit for injection of water as well as gas in determining gas-oil ratio penalties. In this regard only that portion of the volume of water injected in excess of that produced from the pool or part thereof should be considered in calculating gas-oil ratio penalties. However, the Board recognizes that in some instances conservation may not be served by the return of produced water, such as where the oil column is situated between and in communication with a gas cap and aquifer and the displacement of oil into the gas cap might reduce the oil recoverable from the pool. In other instances the water may be injected at a point remote from the producing wells with the result that it would have little beneficial effect on oil recovery from the part of the pool. The Board believes that in these instances and others where the effects may not be beneficial, in the interests of conservation, no credit or a reduced credit for injection of fluids other than gas should be given in the determination of GOR penalty factors.

Applications for approval of the use of the net volume of water injected converted to an equivalent gas volume in determining the gas-oil ratio penalties will be considered by the Board at any time after May 1, 1965.

VII SUMMARY AND DETAILS OF THE NEW PLAN FOR MAXIMUM OIL PRODUCTION RATE LIMITATION

The Board and its staff have given detailed consideration to the evidence and opinions presented at the hearing held during November, 1964, for the purpose of reviewing present methods of establishing maximum oil production rate limitations and certain inconsistencies in the use of its gas-oil ratio penalty tables. The Board has concluded that the present methods have deficiencies and should be replaced by a new plan. Details of the views of industry and of the Board are provided in Sections I to VI of this report. Particulars of the new plan are summarized below.

Scope of Plan

The Board believes that, having in mind the need for maximum rate limitation for the prevention of waste, there should be no difference in principle in its application to prorated or unprorated pools including heavy crude oil pools. The new plan will, therefore, apply to all of these kinds of pools.

Maximum Pool Rate Limitation

The Board believes that it is necessary in all cases to keep pool performance under careful surveillance. To do this the Board is adopting, as a surveillance device only, the Imperial MMR formula in the following form:

$$PRL = K \times 10^{-6} (U - P/2)$$

where PRL is the Preliminary Rate Limitation for a pool or separable portion, barrels per month

K is a constant

U is the ultimate recoverable reserves in stock tank bbl

P is the cumulative production in stock tank bbl

the value of K will normally be taken as 9,000 but the Board may employ a value of 7,000 or 11,000 where, in its opinion, a pool's characteristics and recovery mechanism are such as to suggest it. The Board staff will determine the PRL for each pool or separable portion for which a maximum rate limitation has not, following an MER or equivalent study including a study leading to the approval of an enhanced recovery operation, otherwise been established or recognized by the Board. When it appears that the production from a pool might soon approach the PRL the operators in the pool will be asked to make an MER or equivalent study and submit it to the Board. Following consideration of the submission the Board will determine the need for an MRL, and if necessary set one. Notwithstanding the foregoing an MER or equivalent study may be filed with the Board for consideration at any time.

Period over which Pool Maximum Rate Limitations Will Apply

The Board has decided that maximum rate limitations on a daily basis in pools or pool segments are not necessary and that where limitations are required suitable maximum monthly rate limitations will be set.

Minimum Level of Pool Maximum Rate Limitation

In the case of prorated pools, the maximum rate limitation will be not less than the sum of the lesser for each well of the minimum allowance or the productivity. Furthermore, it is desirable that operators, particularly of minimum allowance pools, have some flexibility, in addition to that provided by the proration plan and related regulations, in producing their allowables. To accomplish this the minimum level of the MRL assigned to a pool or a segment of a pool will be 110 per cent of the sum of the lesser for each well of the minimum allowance or the productivity.

In the case of unprorated pools the minimum level of the pool MRL will be determined having regard to production economics and necessary flexibility.

Applicability of Maximum Rate Limitation to Portions of Pools

The Board has decided that maximum rate limitations are applicable to pools and to distinct parts of pools. In the case of pattern floods the PRL or MRL will apply to the full area of each project, rather than to each pattern or to the entire area of the pool subject to flood by the same fluid.

Distribution of the Pool Maximum Rate Limitation

In pools or portions of pools subject to an MRL and competitively operated, the MRL will, where necessary, be distributed among the wells on the basis of the areas of their production spacing units, subject to any necessary modification to provide the opportunity for individual wells to produce the minimum allowance attributed to the well or wells in a production spacing unit.

Implementation of Pool Maximum Rate Limitations

For those unprorated pools where GOR and WOR penalties are applied, the Board will set MRL's effective May 1, 1965. These will be tentative maximum rate limitations, set having regard to current maximum production rates and the PRL formula, and will be subject to review on application. With respect to all other pools where MER's or the equivalent have not been established or recognized by the Board, the Board staff will begin a review in May, 1965. Where it appears to the Board to be desirable that an MRL study be made for a pool, the operators will be asked to prepare such a study and submit it to the Board within a suitable period.

Individual Well Maximum Rate Limitation

The Board believes it should have provision for the application of individual well daily or monthly maximum rates where the ultimate oil recovery from the pool may otherwise be adversely affected. Where, by the surveillance of such matters as WOR and GOR, reservoir characteristics at the well, individual well productivity or the like, it appears to the

Board that individual well MRL's are necessary in a pool or part of a pool, it will request a submission from the operators concerned, will consider the evidence at hand, and will prescribe daily or monthly individual well MRL's if such appear appropriate.

Control of Gas Production

The Board has decided to adopt its staff's recommendation respecting the procedure to be followed in selecting the gas-oil ratio penalty table under Schedule A applicable to a particular pool. Accordingly the penalty table assigned to a pool will be that numerically nearest the calculated critical GOR provided that it is at least 200 cubic feet per barrel greater than the initial solution GOR. The calculated critical GOR shall be the sum of the volume of 0.5 initial reservoir barrels of free gas in standard cubic feet and the initial solution GOR.

The Board believes that tables based on critical GOR's below that of 1,000 should be applied where appropriate. Subject to modifications indicated, the Board is adopting the rules proposed by the Board staff.

The new method for calculating the penalty base and the subject tables will apply by the rules proposed by the Board staff, effective May 1, 1965, to pools designated after April 30, 1965, and to all pools as of May 1, 1966. In any case where there would be serious adverse effects on the economics of gas gathering or processing due to these changes and an operator would suffer hardship thereby, the Board will consider an application for an extension of the use of the current method of calculating the penalty base and the current tables.

Where transfer of economic allowances from injection wells becomes warranted during the period prior to May 1, 1968, and the terminal transfer point is not presently prescribed, it will be determined, in the case of pools designated prior to May 1, 1965, using the GOR penalty table in effect at April 30, 1965. In the case of pools designated after April 30, 1965, it will be determined using the table in effect at the time the terminal transfer recovery curve for the pool is adopted by the Board.

Credit for Injection of Water

Subject to a few exceptions, the Board will give credit in the calculation of GOR penalties for the injection of water in excess of that produced from the pool or part thereof. The exceptions will include cases where conservation may not be served by the injection of water or where the water is introduced at a point remote from the producing wells with the result that it would have little beneficial effect on oil recovery from the pool. Applications for approval of the use of the net volume of water injected converted to an equivalent gas volume in determining the GOR penalties will be considered by the Board at any time after May 1, 1965.

Calgary, Alberta
March 15, 1965.

APPENDIX A

MPR FORMULA DOCUMENTS

PROPOSED GENERAL FORMULA FOR THE CALCULATION OF "MPR's"

Recognizing the desirability of a general and uniform procedure for determining the "maximum permissible rate" of production of crude oil producing wells, the Board is giving thought to the adoption of an "MPR" formula. The "MPR" is the Board's engineering estimate of the individual well maximum efficient rate of production.

Early in the development of a pool, little information is available regarding the size or the producing characteristics of the reservoir. In fact, a rigorous analysis is seldom possible until at least 10% of the ultimate recovery has been obtained. In view of this fact, it is suggested that volumetric considerations should be used to establish the MPR for a typical well in a pool until such time as production history might indicate that a change in the method of MPR calculation be made.

It is generally recognized that the maximum permissible rate of production of a typical well in a pool may be related to the following variables:

1. Acreage
2. Pay thickness
3. Porosity, connate water, shrinkage
4. Nature of reservoir drive
5. Expected recovery
6. Life of the pool
7. Degree of development of the pool
8. Reservoir pressure
9. Producing gas-oil ratio
10. Producing water-oil ratio

Variables 4, 5 and 6 are interrelated; variables 5 and 6 being in fact, determined by variable 4, the nature of the reservoir drive. Variable 7, the degree of development of the pool, is significant since a greater per-well withdrawal may be tolerated without reservoir damage before the pool is completely drilled out. Variables 8, 9 and 10 are separately significant only as differences may develop among the wells in a given pool. It is suggested that these variables may be combined in a single general formula.

The proposed formula contemplates the definition of what might be termed a "reference well". This reference well would be a typical well, having an assigned production area of 40 acres in a pool of average pay thickness equal to "T" feet, having the following average properties:

porosity = $f = 0.10$

connate water = $c = 0.25$

shrinkage = $s = 0.75$

and having other reservoir properties such that an ultimate recovery, "R" of 0.20 would be obtained in a "uniform rate" life, "L" of 10 years. For this reference well, the MPR may be calculated as the net recoverable stock tank oil divided by the number of days in the "uniform rate" life "L" of 10 years.

i.e.
$$\text{MPR} = \left(7758 \frac{\text{Bbl.}}{\text{acre-ft}}\right)\left(\frac{40T \text{ acre-ft.}}{10(365) \text{ days}}\right)\left(0.10 \text{ porosity}\right)\left(1-0.25 \text{ connate}\right)$$

$$\ldots .\ (0.75 \text{ shrinkage})(0.20 \text{ recovery})$$

$$\text{MPR} = (0.9655\ T)$$

or, practically

$$\text{MPR} = T \text{ bbl/day.}$$

This formula assumes that the reference well is in a pool which is fully developed. For other cases, i.e. early in the development life of a pool, the reference well formula would be modified by the incorporation of a "degree of development" factor, F_D. This factor might ideally be related to the fractional development of the pool. Since the areal magnitude of any pool upon discovery is impossible to define, it is suggested that a maximum development factor, $F_D = 3.0$ be used to calculate the MPR of a typical well in a newly discovered pool, until such time as the size of the pool be fairly well known. In the case of large pools, the factor $F_D = 3.0$ might apply for a year. However, when a pool is recognized to be small early in its development history, the F_D factor might be altered from the value 3.0 to a different value within six months, such that it would be roughly proportional to the fractional development of the pool.

The formula for the reference well would therefore be:

$$\text{MPR} = T\, F_D \text{ bbls/day.}$$

For actual wells the formula would be modified in accordance with the differences from the reference well in the assigned acreage, porosity, connate water, shrinkage, and expected recovery and life as determined by the nature of the reservoir drive. These modifications may most readily be incorporated through the use of the following additional factors:

F_A = acreage factor

= 1/40 (acreage assigned for production purposes)

F_{PS} = porosity-shrinkage factor

$$= \frac{f\ (1-c)\ s}{0.10\ (0.75)(0.75)}$$

where f = average pool porosity, fraction

c = average pool connate water, fraction

s = average pool shrinkage, fraction

0.10 = reference well porosity, fraction

0.75 = 1- reference well connate water, fraction

0.75 = reference well shrinkage, fraction

F_{RL} = recovery-life factor

$$= \frac{10R}{0.20L}$$

where 10 = reference well "uniform rate" life, years

L = expected "uniform rate" life, years

R = expected recovery, fraction

0.20 = reference well recovery, fraction

The factor F_A above would alter the reference well MPR equation to apply to actual wells on assigned production areas of other than 40 acres. Similarly the factor F_{PS} would modify the reference well formula to apply to an actual well in a pool where the porosity, connate water and shrinkage are different than those values assigned to the reference well.

The recovery-life factor F_{RL} would modify the reference well formula such that the calculated MPR would apply to an actual pool in which the reservoir drive characteristics could be expected to lead to a recovery value different than 0.20 and a "uniform rate" life different than 10 years. It is interesting to note that the ratio R/L would not vary greatly since R and L are somewhat related. The limits of variation would probably be from 0.02 to 0.03.

The resulting modified equation for a typical well in any pool would take the form

$$MPR = T \quad F_D \quad F_A \quad F_{PS} \quad F_{RL}$$

As differences developed between individual wells in a pool, further modifying factors might be required to adjust the MPR of a well for changes in reservoir pressure, producing gas-oil ratio or producing water-oil ratio. The following additional modifying factors could then be applied to the general equation above:

F_P = reservoir pressure penalty factor, to be determined.

F_G = gas-oil ratio penalty factor, to be determined.

F_W = water-oil ratio penalty factor, to be determined.

The general equation for the MPR of a typical well in any pool would then be

$$MPR = T \quad F_D \quad F_A \quad F_{PS} \quad F_{RL} \quad F_P \quad F_G \quad F_W$$

The reference conditions have been chosen to be conservative so that early in the life of the pool when little data are available, the MPR may be selected safely, merely by taking all factors except the thickness T, and the degree of development, F_D as unity.

Except for the penalty factors, F_P, F_G, and F_W and the development factor F_D, the final formula, like that for the reference well is a statement of the recoverable reserve of stock tank oil divided by the number of days in the expected uniform rate life of the pool. As such the formula is subject to criticism on the basis that many of the factors, and especially the recovery and the life are not subject to accurate determination until the pool has been completely produced. While this is true, it is also true that these factors can be estimated, even early in the life of the pool, by comparison with other pools and by observations indicative of the type of reservoir drive.

It is suggested that for some period of time, possibly three months, immediately after discovery of a new pool, the formula would not be applied since the factors would not be known to any degree of accuracy. The numerical values of the various factors would be determined as the result of a public hearing, and would necessarily be under continual revision, especially during the early life of the pool. Also it is suggested that there be a minimum value for the MPR, possibly 20 barrels per day, which would apply if the calculated value were less than 20 barrels per day.

It is suggested that the proposed formula has the following merits:

(1) It is comparatively simple.

(2) It is general and flexible and can take account of the extremes in the values of the variables previously listed (Page 1.)

(3) It permits equity in the determination of the MPR's of wells in different pools.

(4) It may with safety and realism be adopted early in the life of the pool.

(5) Its adoption would enable operators to plan their future development with a greater knowledge of future production rates.

(6) It is contemplated that the adoption of such a formula would expedite the conduct of "allowable hearings" and would serve to organize the engineering discussion and to focus it upon the problem of arriving at the best values of the various factors.

THE PETROLEUM AND NATURAL GAS CONSERVATION BOARD
PROVINCE OF ALBERTA

PLEASE REFER TO FILE NO. ____________

I. N. MCKINNON,
CHAIRMAN
D. P. GOODALL, P. ENG.,
DEPUTY CHAIRMAN
G. W. GOVIER, P. ENG.,
BOARD MEMBER
VERNON MILLARD,
SECRETARY TO THE BOARD

603 - 6TH AVENUE S.W.
CALGARY, ALBERTA

January 30th, 1957

To All Operators

Dear Sirs:

Re: The Use of the Development Factor in the MPR Formula for Oil Wells

You will recall the Board's memorandum of September 26th, 1956, and the public hearings held by the Board on October 9th and November 6th on the above matter. The Board has given careful consideration to the evidence submitted and the views expressed at the hearings and has had extensive discussions with its staff on the entire question.

A considerable proportion of the evidence at the two hearings related to the desirability of a "discovery and early development bonus" and appeared to favor the retention of the development factor for providing such a bonus. The Board remains unconvinced of the necessity of a discovery bonus beyond that provided by the exemption from proration of wells outside Board defined fields, and in any event is not prepared to see the development factor serve as such a bonus. If the bonus concept is removed from considerations of the development factor, then it appears to the Board that the preponderance of well supported opinion expressed at the Hearings favors the elimination of the development factor over a transition period. The Board staff and the Board concur in this opinion, and the Board has decided upon the complete elimination of the development factor in the formula for calculating oil well MPR's. This elimination will take place gradually by a stepwise reduction in the maximum development factor permitted in any pool in accordance with the following schedule:

Period	Maximum Development Factor
Present time to April 30th, 1958	2.5
May 1st, 1958 to April 30th, 1959	1.75
May 1st, 1959 and thereafter	F_D Eliminated

With respect to the question of the discovery bonus, the Board plans to continue its present practice of setting liberal individual well MPR's for all oil wells outside Board defined fields and will continue to exempt them from proration to market demand.

Yours very truly,

I. N. McKinnon,
Chairman.

OIL AND GAS CONSERVATION BOARD
PROVINCE OF ALBERTA

PLEASE REFER TO FILE NO.____________

G. W. GOVIER, P.ENG.,
DEPUTY CHAIRMAN
A. F. MANYLUK, P.ENG.,
BOARD MEMBER
VERNON MILLARD,
ACTING BOARD MEMBER

603 - 6TH AVENUE S.W.
CALGARY, ALBERTA

February 3, 1960.

To All Operators:

RE: DATA SUMMARY FOR MPR AND MER SUBMISSIONS

The Board requests that, with the exception of individual project MPR submissions for the Pembina Cardium Pool, all MPR and MER submissions for the hearings to be held on March 15 and 22, 1960, be accompanied by six copies of a completed data summary in the form attached. The summary will facilitate comparison of data presented in the submission with that of other pools and with the data prepared by the Board's staff, thereby simplifying the hearings. Copies of the form are available at the office of the Board, 603 - 6th Avenue S.W., Calgary, Alberta.

Operators will note that the summary calls for both basic data required for an MPR type calculation and certain supplementary data. The MPR calculation is based on the MPR equation expressed as:

$$\text{MPR} = \frac{F_A\ R_i\ N_{40}}{365\ F_L\ L_{40}}$$

where

R_i = Estimated recovery, fraction.

N_{40} = Initial oil in place per average 40 acre tract, stock tank barrels.

F_A = Acreage factor, acreage of spacing unit divided by 40.

L_{40} = Estimated uniform-rate life of an average well if drilled on 40 acre spacing, years.

F_L = Life factor, ratio of the estimated uniform-rate life of an average well drilled on the actual spacing to that if the spacing were 40 acres.

The use of the porosity - shrinkage factor (F_{PS}) and the recovery-life factor (F_{RL}) employed in the earlier form of the MPR equation is discontinued. In order that the summary may serve the function intended it is important that the form be completed in conformity to the definitions which are given on its reverse side.

I am instructed by the Board to stress the fact that, in requesting operators to submit their basic data in a uniform manner, the Board is not asking that submissions be in any way standardized or restricted. The Board expects and desires that operators will make submissions of whatever type they wish, but simply requests that in each case the submission be accompanied by the completed forms.

D. R. Craig,
Reservoir Engineer

DRC/ec

OIL AND GAS CONSERVATION BOARD
PROVINCE OF ALBERTA

PLEASE REFER TO FILE NO.________________

G. W. GOVIER, P.ENG.,
DEPUTY CHAIRMAN
A. F. MANYLUK, P.ENG.,
BOARD MEMBER
VERNON MILLARD,
ACTING BOARD MEMBER

603 - 6TH AVENUE S.W.
CALGARY, ALBERTA

November 25, 1960.

To All Operators:

RE: Well Productivity in relation to MPR's

For the past several months the Board and its staff have been reviewing the relationship between well productivity and the MPR values established for crude oil wells. A number of representations have been made on the subject at the Spring and Fall MPR hearings, principally in connection with the Pembina Cardium Pool. The Board believes that a statement of its views on this subject is needed at this time.

The MPR's themselves are based on recoverable reserves and an estimated "life" which for forty acre spacing has been taken as some seven to fourteen years depending upon reservoir conditions. The Board has always had in mind however that the MPR value established for a well should be subject to a lower and an upper limit, the lower limit being the economic allowance and the upper limit being the productivity of the average well in the pool. The Board is sure that there is general concurrence among the operators with this concept.

Nevertheless, there appears to be a lack of agreement among operators, and some difference in interpretation within the Board organization, with respect to the period of time over which the productivity of the well should be assessed. The extreme positions taken are, on one hand that productivity for an MPR period of six to twelve months is sufficient, and on the other hand that productivity equal to or greater than the MPR should be required for a substantial portion of that life which is used to calculate the MPR. The Board suggested the latter criterion in its letter to all operators of May 27, 1960, but has never formally adopted it.

.... 2

To All Operators:

November 25, 1960.

The Board has examined the practice it has been following in recent years and finds that, while many of the pools in the Province meet the more stringent of the two positions, there are a significant number of pools in which the average well could not produce at the subsisting MPR for more than two or three years. The Board now believes that only the current average well productivity need be considered as a ceiling on the calculated MPR. Where productivity considerations do control, MPR's would be successively reduced in the future as the productivity declined.

The Board has therefore decided to adopt a productivity requirement such that the MPR for a well in a pool shall be not greater than eighty per cent of the estimated current productivity of an average well in the pool. This requirement is being made effective for the forthcoming MPR period. However, the Board is prepared to give further consideration to the matter if there appears to be dissatisfaction among the operators.

Yours very truly,

DRC/ec

A. F. Manyluk,
Board Member.

APPENDIX B

GAS-OIL AND WATER-OIL RATIO PENALTY FACTOR SCHEDULES

SCHEDULE A

Gas - Oil Ratios' Plus Separator Pressure

Gas-Oil Ratio Penalty Factor	Table 200	Table 400	Table 600	Table 800	Table 1000	Table 1100	Table 1200	Table 1300	Table 1400	Table 1500	Table 1600	Table 1800	Table 2000	Gas-Oil Ratio Penalty Factor
1.00	0-201	0-402	0-603	0-804	0-1005	0-1106	0-1206	0-1307	0-1407	0-1508	0-1608	0-1810	0-2011	1.00
0.99	202-203	403-406	604-609	805-812	1006-1015	1107-1117	1207-1218	1308-1320	1408-1422	1509-1523	1609-1625	1811-1828	2012-2031	0.99
0.98	204-205	407-410	610-615	813-820	1016-1026	1118-1128	1219-1231	1321-1334	1423-1436	1524-1539	1626-1641	1829-1847	2032-2052	0.98
0.97	206-207	411-414	616-622	821-829	1027-1036	1129-1140	1232-1244	1335-1347	1437-1451	1540-1555	1642-1658	1848-1866	2053-2073	0.97
0.96	208-209	415-419	623-628	830-838	1037-1047	1141-1152	1245-1257	1348-1362	1452-1466	1556-1571	1659-1676	1867-1885	2074-2095	0.96
0.95	210-211	420-423	629-635	839-847	1048-1058	1153-1164	1258-1270	1363-1376	1467-1482	1572-1588	1677-1694	1886-1905	2096-2117	0.95
0.94	212-214	424-428	636-642	848-856	1059-1070	1165-1177	1271-1284	1377-1391	1483-1498	1589-1605	1695-1712	1906-1926	2118-2140	0.94
0.93	215-216	429-432	643-649	857-865	1071-1081	1178-1189	1285-1298	1392-1406	1499-1514	1606-1622	1713-1730	1927-1947	2141-2163	0.93
0.92	217-218	433-437	650-656	866-874	1082-1093	1190-1202	1299-1312	1407-1421	1515-1530	1623-1640	1731-1749	1948-1968	2164-2187	0.92
0.91	219-221	438-442	657-663	875-884	1094-1105	1203-1216	1313-1326	1422-1437	1531-1547	1641-1658	1750-1769	1969-1990	2188-2211	0.91
0.90	222-223	443-447	664-670	885-894	1106-1118	1217-1229	1327-1341	1438-1453	1548-1565	1659-1677	1770-1788	1991-2012	2212-2236	0.90
0.89	224-226	448-452	671-678	895-904	1119-1130	1230-1243	1342-1356	1454-1469	1566-1582	1678-1695	1789-1809	2013-2035	2237-2261	0.89
0.88	227-228	453-457	679-686	905-914	1131-1143	1244-1257	1357-1372	1470-1486	1583-1601	1696-1715	1810-1829	2036-2058	2262-2287	0.88
0.87	229-231	458-462	687-694	915-925	1144-1156	1258-1272	1373-1388	1487-1503	1602-1619	1716-1735	1830-1850	2059-2082	2288-2313	0.87
0.86	232-234	463-468	695-702	926-936	1157-1170	1273-1287	1389-1404	1504-1521	1620-1638	1736-1755	1851-1872	2083-2106	2314-2340	0.86
0.85	235-236	469-473	703-710	937-947	1171-1184	1288-1302	1405-1421	1522-1539	1639-1657	1756-1776	1873-1894	2107-2131	2341-2368	0.85
0.84	237-239	474-479	711-719	948-958	1185-1198	1303-1318	1422-1438	1540-1557	1658-1677	1777-1797	1895-1917	2132-2157	2369-2396	0.84
0.83	240-242	480-485	720-727	959-970	1199-1212	1319-1334	1439-1455	1558-1576	1678-1698	1798-1819	1918-1940	2158-2183	2397-2425	0.83
0.82	243-245	486-491	728-736	971-982	1213-1227	1335-1350	1456-1473	1577-1596	1699-1718	1820-1841	1941-1964	2184-2210	2426-2455	0.82
0.81	246-248	492-497	737-745	983-994	1228-1243	1351-1367	1474-1491	1597-1616	1719-1740	1842-1864	1965-1988	2211-2237	2456-2486	0.81
0.80	249-251	498-503	746-755	955-1006	1244-1258	1368-1384	1492-1510	1617-1636	1741-1762	1865-1888	1989-2013	2238-2265	2487-2517	0.80
0.79	252-254	504-509	756-764	1007-1019	1259-1274	1385-1402	1511-1529	1637-1657	1763-1784	1889-1912	2014-2039	2266-2294	2518-2549	0.79
0.78	255-258	510-516	765-774	1020-1032	1275-1291	1403-1420	1530-1549	1658-1678	1785-1807	1913-1936	2040-2065	2295-2324	2550-2582	0.78
0.77	259-261	517-523	775-784	1033-1046	1292-1308	1421-1438	1550-1569	1679-1700	1808-1831	1937-1962	2066-2093	2325-2354	2583-2616	0.77
0.76	262-265	524-530	785-795	1047-1060	1309-1325	1439-1458	1570-1590	1701-1723	1832-1855	1963-1988	2094-2120	2355-2385	2617-2650	0.76
0.75	266-268	531-537	796-805	1061-1074	1326-1343	1459-1477	1591-1611	1724-1746	1856-1880	1989-2014	2121-2149	2386-2417	2651-2686	0.75
0.74	269-272	538-544	806-816	1075-1089	1344-1361	1478-1497	1612-1633	1747-1770	1881-1906	2015-2042	2150-2178	2418-2450	2687-2723	0.74
0.73	273-276	545-552	817-828	1090-1104	1362-1380	1498-1518	1634-1656	1771-1794	1907-1932	2043-2070	2179-2208	2451-2484	2724-2760	0.73
0.72	277-279	553-559	829-839	1105-1119	1381-1399	1519-1539	1657-1679	1795-1819	1933-1959	2071-2099	2209-2239	2485-2519	2761-2799	0.72
0.71	280-283	560-567	840-851	1120-1135	1400-1419	1540-1561	1680-1703	1820-1845	1960-1987	2100-2129	2240-2271	2520-2555	2800-2839	0.71
0.70	284-288	568-576	852-864	1136-1152	1420-1440	1562-1584	1704-1728	1846-1872	1988-2016	2130-2160	2272-2304	2556-2592	2840-2880	0.70
0.69	289-292	577-584	865-876	1153-1168	1441-1461	1585-1607	1729-1753	1873-1899	2017-2045	2161-2191	2305-2337	2593-2629	2881-2922	0.69
0.68	293-296	585-593	877-889	1169-1186	1462-1482	1608-1630	1754-1779	1900-1927	2046-2075	2192-2224	2338-2372	2630-2668	2923-2965	0.68
0.67	297-301	594-602	890-903	1187-1204	1483-1505	1631-1655	1780-1806	1928-1956	2076-2107	2225-2257	2373-2408	2669-2709	2966-3010	0.67
0.66	302-305	603-611	904-916	1205-1222	1506-1528	1656-1680	1807-1833	1957-1986	2108-2139	2258-2292	2409-2444	2710-2750	3011-3056	0.66
0.65	306-310	612-620	917-931	1223-1241	1529-1551	1681-1706	1834-1862	1987-2017	2140-2172	2293-2327	2445-2482	2751-2793	3057-3103	0.65
0.64	311-315	621-630	932-945	1242-1260	1552-1576	1707-1733	1863-1891	2018-2049	2173-2206	2328-2364	2483-2521	2794-2837	3104-3152	0.64
0.63	316-320	631-640	946-960	1261-1281	1577-1601	1734-1761	1892-1921	2050-2081	2207-2241	2365-2402	2522-2562	2838-2882	3153-3202	0.63
0.62	321-325	641-650	961-976	1282-1301	1602-1627	1762-1790	1922-1952	2082-2115	2242-2278	2403-2441	2563-2603	2883-2929	3203-3254	0.62
0.61	326-330	651-661	977-992	1302-1323	1628-1654	1791-1819	1953-1985	2116-2150	2279-2316	2442-2481	2604-2647	2930-2977	3255-3308	0.61
0.60	331-336	662-672	993-1009	1324-1345	1655-1682	1820-1850	1986-2018	2151-2186	2317-2355	2482-2523	2648-2691	2978-3028	3309-3364	0.60
0.59	337-342	673-684	1010-1026	1346-1368	1683-1711	1851-1882	2019-2053	2187-2224	2356-2395	2524-2566	2692-2737	3029-3079	3365-3422	0.59
0.58	343-348	685-696	1027-1044	1369-1392	1712-1740	1883-1914	2054-2088	2225-2263	2396-2437	2567-2611	2738-2785	3080-3133	3423-3481	0.58
0.57	349-354	697-708	1045-1062	1393-1417	1741-1771	1915-1948	2089-2125	2264-2303	2438-2480	2612-2657	2786-2834	3134-3188	3482-3543	0.57
0.56	355-360	709-721	1063-1082	1418-1442	1772-1803	1949-1983	2126-2164	2304-2344	2481-2525	2658-2705	2835-2885	3189-3246	3544-3607	0.56
0.55	361-367	722-734	1083-1102	1443-1469	1804-1836	1984-2020	2165-2204	2345-2387	2526-2571	2706-2755	2886-2938	3247-3306	3608-3673	0.55
0.54	368-374	735-748	1103-1122	1470-1496	1837-1871	2021-2058	2205-2245	2388-2432	2572-2619	2756-2806	2939-2993	3307-3367	3674-3742	0.54
0.53	375-381	749-762	1123-1144	1497-1525	1872-1906	2059-2097	2246-2288	2433-2478	2620-2669	2807-2860	2994-3050	3368-3432	3743-3813	0.53
0.52	382-388	763-777	1145-1166	1526-1555	1907-1943	2098-2138	2289-2332	2479-2526	2670-2721	2861-2915	3051-3110	3433-3498	3814-3887	0.52
0.51	389-396	778-792	1167-1189	1556-1585	1944-1982	2139-2180	2333-2378	2527-2577	2722-2775	2916-2973	3111-3171	3499-3568	3888-3964	0.51

Gas - Oil Ratios Plus Separator Pressure

Gas-Oil Ratio Penalty Factor	Table 200	Table 400	Table 600	Table 800	Table 1000	Table 1100	Table 1200	Table 1300	Table 1400	Table 1500	Table 1600	Table 1800	Table 2000	Gas-Oil Ratio Penalty Factor
0.50	397 404	793-808	1190-1213	1586-1617	1983-2022	2181-2224	2379-2426	2578 2629	2776-2831	2974-3033	3172-3235	3569-3640	3965-4044	0.50
0.49	405-412	809-825	1214-1238	1618-1651	2023-2064	2225-2270	2427-2477	2630-2683	2832-2889	3034-3096	3236-3302	3641-3715	4045-4128	0.49
0.48	413-421	826-843	1239-1264	1652-1686	2065-2107	2271 2318	2478-2529	2684-2740	2890-2950	3097-3161	3303-3372	3716-3793	4129-4215	0.48
0.47	422-430	844 861	1265-1291	1687-1722	2108-2153	2319 2368	2530-2583	2741-2799	2951-3014	3162-3229	3373 3444	3794-3875	4216-4306	0.47
0.46	431-440	862-880	1292-1320	1723-1760	2154-2200	2369-2420	2584 2640	2800 2860	3015-3080	3230-3300	3445-3520	3876-3960	4307 4400	0.46
0.45	441-450	881-900	1321 1350	1761 1800	2201-2250	2421-2475	2641-2700	2861-2925	3081-3150	3301-3375	3521-3600	3961-4050	4401-4500	0.45
0.44	451-460	901-920	1351-1381	1801-1841	2251 2301	2476 2531	2701 2762	2926 2992	3151 3222	3376-3452	3601-3682	4051 4143	4501-4603	0.44
0.43	461-471	921-942	1382 1413	1842-1884	2302-2356	2532 2591	2763-2827	2993-3062	3223-3298	3453-3534	3683-3769	4144-4240	4604-4712	0.43
0.42	472-482	943-965	1414-1447	1885-1930	2357-2412	2592-2654	2828-2895	3063-3136	3299-3378	3535-3619	3770 3860	4241-4343	4713-4825	0.42
0.41	483-494	966 989	1448-1483	1931-1978	2413-2472	2655-2719	2896-2967	3137-3214	3379-3461	3620 3708	3861-3956	4344-4450	4826-4945	0.41
0.40	495-507	990-1014	1484-1521	1979-2028	2473-2535	2720-2788	2968 3042	3215-3295	3462-3549	3709-3802	3957-4056	4451-4563	4946-5070	0.40
0.39	508-520	1015-1040	1522-1560	2029 2080	2536-2601	2789-2861	3043 3121	3296-3381	3550-3641	3803-3901	4057-4161	4564-4682	5071-5202	0.39
0.38	521-534	1041-1068	1561-1602	2081-2136	2602-2670	2862-2937	3122-3204	3382-3471	3642-3738	3902-4005	4162-4272	4683-4807	5203-5241	0.38
0.37	535-548	1069-1097	1603-1646	2137-2195	2671-2743	2938-3018	3205-3292	3472-3567	3739-3841	4006-4115	4273-4390	4808-4939	5342-5487	0.37
0.36	549-564	1098 1128	1647-1692	2196-2257	2744-2821	3019-3103	3293-3385	3568 3667	3842-3949	4116-4231	4391-4514	4940 5078	5488-5642	0.36
0.35	565 580	1129-1161	1693-1741	2258-2322	2822-2903	3104-3193	3386-3483	3668-3774	3950-4064	4232-4354	4515-4645	5079-5225	5643-5806	0.35
0.34	581 598	1162 1196	1742-1794	2323-2392	2904-2990	3194-3289	3484-3588	3775-3887	4065-4186	4355-4485	4646-4784	5226-5382	5807-5980	0.34
0.33	599-616	1197-1232	1795-1849	2393-2465	2991-3082	3290-3390	3589-3698	3888-4006	4187-4315	4486-4623	4785-4931	5383-5547	5981-6164	0.33
0.32	17-636	1233-1272	1850-1908	2466-2544	3083-3180	3391-3498	3699-3816	4007-4134	4316 4452	4624-4770	4932 5088	5548 5724	6165-6360	0.32
0.31	637-656	1273 1313	1909-1970	2545-2627	3181-3284	3499 3613	3817-3941	4135-4270	4453-4598	4771-4927	5089-5255	5725-5912	6361-6569	0.31
0.30	657-679	1314-1358	1971 2037	2628-2716	3285-3396	3614-3735	3942-4075	4271 4415	4599-4754	4928-5094	5256-5433	5913-6113	6570-6792	0.30
0.29	680-703	1359-1406	2038-2109	2717-2812	3397-3515	3736-3867	4076-4218	4416-4570	4755-4921	5095-5273	5434-5625	6114-6328	6793-7031	0.29
0.28	704-728	1407-1457	2110-2186	2813-2914	3516-3643	3868-4008	4219-4372	4571-4736	4922 5101	5274-5465	5626-5829	6329-6558	7032-7287	0.28
0.27	729-756	1458-1512	2187 2268	2915-3025	3644-3781	4009-4159	4373-4537	4737-4915	5102-5294	5466-5672	5830-6050	6559-6806	7288-7563	0.27
0.26	757-786	1513-1572	2269-2358	3026-3144	3782-3930	4160-4323	4538-4716	4916-5109	5295-5502	5673-5895	6051-6288	6807-7074	7564-7860	0.26
0.25	787-818	1573 1636	2359 2454	3145-3272	3931-4090	4324-4500	4717-4909	5110-5318	5503-5727	5896-6136	6289-6545	7075-7363	7861-8181	0.25
0.24	819-853	1637-1706	2455-2559	3273-3412	4091-4265	4501-4691	4910-5118	5319-5545	5728-5971	6137-6398	6546 6824	7364-7677	8182-8530	0.24
0.23	854-891	1707-1782	2560-2673	3413-3564	4266-4455	4692-4900	5119-5346	5546-5792	5972-6237	6399-6683	6825-7128	7678-8019	8531-8910	0.23
0.22	892-932	1783-1865	2674-2797	3565-3730	4456-4663	4901-5129	5347-5595	5793 6062	6238-6528	6684-6994	7129-7461	8020-8393	8911 9326	0.22
0.21	933-978	1866-1956	2798-2934	3731-3913	4664-4891	5130-5380	5596-5869	6063-6358	6529-6847	6995-7336	7462-7826	8394-8804	9327-9782	0.21
0.20	979-1028	1957-2057	2935-3085	3914-4114	4892-5142	5381 5657	5870-6171	6359-6685	6848-7200	7337-7714	7827-8228	8805-9257	9783-10285	0.20
0.19	1029-1084	2058-2168	3086-3253	4115-4337	5143-5421	5658-5963	6172-6506	6686-7048	7201-7590	7715-8132	8229 8674	9258-9759	10286-10843	0.19
0.18	1085-1146	2169-2292	3254-3439	4338-4585	5422-5732	5964-6305	6507-6878	7049-7452	7591-8025	8133-8598	8675-9171	9760-10318	10844-11464	0.18
0.17	1147-1216	2293-2432	3440-3648	4586-4864	5733-6081	6306-6689	6879-7297	7453-7905	8026-8513	8599-9121	9172-9729	10319-10945	11465-12162	0.17
0.16	1217-1294	2433-2589	3649-3884	4865-5179	6082-6474	6690-7122	7298-7769	7906-8417	8514-9064	9122-9712	9730-10359	10946-11654	12163-12949	0.16
0.15	1295-1384	2590-2769	3885 4153	5180-5538	6475-6923	7123-7615	7770-8307	8418 9000	9065-9692	9713-10384	10360-11076	11655-12461	12950-13846	0.15
0.14	1385-1487	2770-2975	4154-4462	5539-5950	6924-7438	7616-8181	8308-8925	9001 9669	9693-10413	10385-11157	11077-11900	12462-13388	13847-14876	0.14
0.13	1488 1607	2976-3214	4463-4821	5951-6428	7439-8035	8182-8839	8926-9642	9670-10446	10414-11250	11158-12053	11901-12857	13389-14464	14877-16071	0.13
0.12	1608-1747	3215-3495	4822-5242	6429-6990	8036-8737	8840-9611	9643 10485	10447-11359	11251-12233	12054-13106	12858-13980	14465-15728	16072-17475	0.12
0.11	1748-1914	3496-3829	5243-5744	6991-7659	8738-9574	9612-10531	10486-11489	11360-12446	12234-13404	13107-14361	13981-15319	15729-17234	17476-19148	0.11
0.10	1915-2117	3830-4235	5745 6352	7660-8470	9575-10588	10532-11647	11490-12705	12447-13764	13405-14823	14362-15882	15320-16941	17235-19058	19149-21176	0.10
0.09	2118-2368	4236-4736	6353 7105	8471 9473	10589-11842	11648 13026	12706-14210	13765-15394	14824-16578	15883-17763	16942-18947	19059-21315	21177-23684	0.09
0.08	2369-2686	4737-5373	7106-8059	9474-10746	11843-13432	13027-14776	14211-16119	15395-17462	16579-18805	17764-20149	18948-21492	21316-24179	23685-26865	0.08
0.07	2687-3103	5374-6206	8060-9310	10747-12413	13433-15517	14777-17068	16120-18620	17463-20172	18806-21724	20150-23275	21493-24827	24180-27931	26866-31034	0.07
0.06	3104-3673	6207-7346	9311-11020	12414-14693	15518-18367	17069-20204	18621-22040	20173-23877	21725-25714	23276 27551	24828-29387	27932-33061	31035-36734	0.06
0.05	3674-4500	7347-9000	11021-13500	14694-18000	18368-22500	20205-24750	22041-27000	23878-29250	25715-31500	27552-33750	29388 36000	33062-40500	36735-45000	0.05
0.04	4501-5806	9001-11612	13501-17419	18001-23225	22501-29032	24751 31935	27001-34838	29251-37741	31501-40645	33751 43548	36001-46451	40501-52258	45001 58064	0.04
0.03	5807-8181	11613 16363	17420-24545	23226-32727	29033-40909	31936-45000	34839-49090	37742-53181	40646-57272	43549 61363	46452-65454	52259-73636	58065-81818	0.03
0.02	8182-13846	16364-27692	24546-41538	32728-55384	40910-69230	45001-76153	49091-83076	53182-90000	57273-96923	61364-103846	65455-110769	73637-124615	81819-138461	0.02
0.01	13847-45000	27693-90000	41539-135000	55385-180000	69231-225000	76154-247500	83077 270000	90001-292500	96924-315000	103847-337500	110770 360000	124616-405000	138462-450000	0.01

SCHEDULE A

Gas-Oil Ratio Penalty Factor	Gas - Oil Ratios Plus Separator Pressure							Gas-Oil Ratio Penalty Factor
	Table 2200	Table 2500	Table 3000	Table 3500	Table 4000	Table 4500	Table 5000	
1.00	0-2212	0-2513	0-3016	0-3519	0-4022	0-4525	0-5027	1.00
0.99	2213-2234	2514-2539	3017-3047	3520-3555	4023-4063	4526-4571	5028-5079	0.99
0.98	2235-2257	2540-2565	3048-3078	3556-3591	4064-4104	4572-4618	5080-5131	0.98
0.97	2258-2281	2566-2592	3079-3110	3592-3629	4105-4147	4619-4665	5132-5184	0.97
0.96	2282-2305	2593-2619	3111-3143	3630-3667	4148-4190	4666-4714	5185-5238	0.96
0.95	2306-2329	2620-2647	3144-3176	3668-3705	4191-4235	4715-4764	5239-5294	0.95
0.94	2330-2354	2648-2675	3177-3210	3706-3745	4236-4280	4765-4815	5295-5350	0.94
0.93	2355-2379	2676-2704	3211-3245	3746-3786	4281-4326	4816-4867	5351-5408	0.93
0.92	2380-2405	2705-2733	3246-3280	3787-3827	4327-4374	4868-4921	5409-5467	0.92
0.91	2406-2432	2734-2764	3281-3316	3828-3069	4375-4422	4922-4975	5468-5528	0.91
0.90	2433-2459	2765-2795	3317-3354	3870-3913	4423-4472	4976-5031	5529-5590	0.90
0.89	2460-2487	2796-2826	3355-3391	3914-3957	4473-4522	5032-5087	5591-5653	0.89
0.88	2488-2515	2827-2858	3392-3430	3958-4002	4523-4574	5088-5146	5654-5717	0.88
0.87	2516-2544	2859-2892	3431-3470	4003-4048	4575-4627	5147-5205	5718-5784	0.87
0.86	2545-2574	2893-2925	3471-3511	4049-4096	4628-4681	5206-5266	5785-5851	0.86
0.85	2575-2605	2926-2960	3512-3552	4097-4144	4682-4736	5267-5328	5852-5921	0.85
0.84	2606-2636	2961-2996	3553-3595	4145-4194	4737-4793	5329-5392	5922-5992	0.84
0.83	2637-2668	2997-3032	3596-3638	4195-4245	4794-4851	5393-5458	5993-6064	0.83
0.82	2669-2701	3033-3069	3639-3683	4246-4297	4852-4911	5459-5525	6065-6139	0.82
0.81	2702-2734	3070-3107	3684-3729	4298-4350	4912-4972	5526-5593	6140-6215	0.81
0.80	2735-2769	3108-3146	3730-3776	4351-4405	4973-5034	5594-5664	6216-6293	0.80
0.79	2770-2804	3147-3186	3777-3824	4406-4461	5035-5099	5665-5736	6294-6373	0.79
0.78	2805-2840	3187-3228	3825-3873	4462-4519	5100-5164	5737-5810	6374-6456	0.78
0.77	2841-2877	3229-3270	3874-3924	4520-4578	5165-5232	5811-5886	6457-6540	0.77
0.76	2878-2916	3271-3313	3925-3976	4579-4639	5233-5301	5887-5964	6541-6627	0.76
0.75	2917-2955	3314-3358	3977-4029	4640-4701	5302-5373	5965-6044	6628-6716	0.75
0.74	2956-2995	3359-3403	4030-4084	4702-4765	5374-5446	6045-6127	6717-6807	0.74
0.73	2996-3036	3404-3450	4085-4141	4766-4831	5447-5521	6128-6211	6808-6901	0.73
0.72	3037-3079	3451-3499	4142-4199	4832-4898	5522-5598	6212-6298	6902-6998	0.72
0.71	3080-3123	3500-3548	4200-4258	4899-4968	5599-5678	6299-6388	6999-7097	0.71
0.70	3124-3168	3549-3600	4259-4320	4969-5040	5679-5760	6389-6480	7098-7200	0.70
0.69	3169-3214	3601-3652	4321-4383	5041-5113	5761-5844	6481-6574	7201-7305	0.69
0.68	3215-3261	3653-3706	4384-4448	5114-5189	5845-5930	6575-6672	7306-7413	0.68
0.67	3262-3311	3707-3762	4449-4515	5190-5267	5931-6020	6673-6772	7414-7525	0.67
0.66	3312-3361	3763-3820	4516-4584	5268-5348	6021-6112	6773-6876	7526-7640	0.66
0.65	3362-3413	3821-3879	4585-4655	5349-5431	6113-6206	6877-6982	7641-7758	0.65
0.64	3414-3467	3880-3940	4656-4728	5432-5516	6207-6304	6983-7092	7759-7880	0.64
0.63	3468-3523	3941-4003	4729-4804	5517-5604	6305-6405	7093-7206	7881-8007	0.63
0.62	3524-3580	4004-4068	4805-4882	5605-5696	6406-6509	7207-7323	8008-8137	0.62
0.61	3581-3639	4069-4136	4883-4963	5697-5790	6510-6617	7324-7444	8138-8272	0.61
0.60	3640-3700	4137-4205	4964-5046	5791-5887	6618-6728	7445-7570	8273-8411	0.60
0.59	3701-3764	4206-4277	5047-5133	5888-5988	6729-6844	7571-7699	8412-8555	0.59
0.58	3765-3829	4278-4352	5134-5222	5989-6092	6845-6963	7700-7833	8556-8704	0.58
0.57	3830-3897	4353-4429	5223-5314	6093-6200	6964-7086	7834-7972	8705-8858	0.57
0.56	3898-3967	4430-4509	5315-5410	6201-6312	7087-7214	7973-8116	8859-9018	0.56
0.55	3968-4040	4510-4591	5411-5510	6313-6428	7215-7346	8117-8265	9019-9183	0.55
0.54	4041-4116	4592-4677	5511-5613	6429-6548	7347-7484	8266-8419	9184-9355	0.54
0.53	4117-4194	4678-4766	5614-5720	6549-6673	7485-7627	8420-8580	9356-9533	0.53
0.52	4195-4276	4767-4859	5721-5831	6674-6803	7628-7775	8581-8747	9534-9719	0.52
0.51	4277-4361	4860-4955	5832-5947	6804-6938	7776-7929	8748-8920	9720-9911	0.51
0.50	4362-4449	4956-5056	5948-6067	6939-7078	7930-8089	8921-9101	9912-10112	0.50
0.49	4450-4541	5057-5160	6068-6192	7079-7224	8090-8256	9102-9288	10113-10321	0.49
0.48	4542-4637	5161-5269	6193-6323	7225-7377	8257-8430	9289-9484	10322-10538	0.48
0.47	4638-4736	5270-5382	6324-6459	7378-7535	8431-8612	9485-9688	10539-10765	0.47
0.46	4737-4841	5383-5501	6460-6601	7536-7701	8613-8801	9689-9902	10766-11002	0.46
0.45	4842-4950	5502-5625	6602-6750	7702-7875	8802-9000	9903-10125	11003-11250	0.45
0.44	4951-5063	5626-5754	6751-6905	7876-8056	9001-9207	10126-10358	11251-11508	0.44
0.43	5064-5183	5755-5890	6906-7068	8057-8246	9208-9424	10359-10602	11509-11780	0.43
0.42	5184-5308	5891-6032	7069-7238	8247-8445	9425-9651	10603-10857	11781-12064	0.42
0.41	5309-5439	6033-6181	7239-7417	8446-8653	9652-9890	10858-11126	12065-12362	0.41
0.40	5440-5577	6182-6338	7418-7605	8654-8873	9891-10140	11127-11408	12363-12676	0.40
0.39	5578-5722	6339-6502	7606-7803	8874-9104	10141-10404	11409-11705	12677-13005	0.39
0.38	5723-5875	6503-6676	7804-8011	9105-9347	10405-10682	11706-12017	13006-13353	0.38
0.37	5876-6036	6677-6859	8012-8231	9348-9603	10683-10975	12018-12347	13354-13719	0.37
0.36	6037-6206	6860-7053	8232-8463	9604-9874	10976-11285	12348-12695	13720-14106	0.36
0.35	6207-6387	7054-7258	8464-8709	9875-10161	11286-11612	12696-13064	14107-14516	0.35
0.34	6388-6578	7259-7475	8710-8970	10162-10465	11613-11960	13065-13455	14517-14950	0.34
0.33	6579-6780	7476-7705	8971-9246	10466-10787	11961-12328	13456-13869	14951-15410	0.33
0.32	6781-6996	7706-7950	9247-9540	10788-11130	12329-12720	13870-14310	15411-15901	0.32
0.31	6997-7226	7951-8211	9541-9854	11131-11496	12721-13138	14311-14781	15902-16423	0.31
0.30	7227-7471	8212-8490	9855-10188	11497-11886	13139-13584	14782-15283	16424-16981	0.30
0.29	7472-7734	8491-8789	10189-10546	11887-12304	13585-14062	15284-15820	16982-17578	0.29
0.28	7735-8016	8790-9109	10547-10931	12305-12753	14063-14574	15821-16396	17579-18218	0.28
0.27	8017-8319	9110-9453	10932-11344	12754-13235	14575-15126	16397-17016	18219-18907	0.27
0.26	8320-8646	9454-9825	11345-11790	13236-13755	15127-15720	17017-17685	18908-19650	0.26
0.25	8647-9000	9826-10227	11791-12272	13756-14318	15721-16363	17686-18409	19651-20454	0.25
0.24	9001-9383	10228-10663	12273-12796	14319-14928	16364-17061	18410-19194	20455-21327	0.24
0.23	9384-9801	10664-11138	12797-13366	14929-15594	17062-17821	19195-20049	21328-22277	0.23
0.22	9802-10259	11139-11658	13367-13989	15595-16321	17822-18652	20050-20984	22278-23316	0.22
0.21	10260-10760	11659-12228	13990-14673	16322-17119	18653-19565	20985-22010	23317-24456	0.21
0.20	10761-11314	12229-12857	14674-15428	17120-18000	19566-20571	22011-23142	24457-25714	0.20
0.19	11315-11927	12858-13554	15429-16265	18001-18975	20572-21686	23143-24397	25715-27108	0.19
0.18	11928-12611	13555-14331	16266-17197	18976-20063	21687-22929	24398-25796	27109-28662	0.18
0.17	12612-13378	14332-15202	17198-18243	20064-21283	22930-24324	25797-27364	28663-30405	0.17
0.16	13379-14244	15203-16187	18244-19424	21284-22661	24325-25899	27365-29136	30406-32374	0.16
0.15	14245-15230	16188-17307	19425-20769	22662-24230	25900-27692	29137-31153	32375-34615	0.15
0.14	15231-16363	17308-18595	20770-22314	24231-26033	27693-29752	31154-33471	34616-37190	0.14
0.13	16364-17678	18596-20089	22315-24107	26034-28125	29753-32142	33472-36160	37191-40178	0.13
0.12	17679-19223	20090-21844	24108-26213	28126-30582	32143-34951	36161-39320	40179-43689	0.12
0.11	19224-21063	21845-23936	26214-28723	30583-33510	34952-38297	39321-43085	43690-47872	0.11
0.10	21064-23294	23937-26470	28724-31764	33511-37058	38298-42352	43086-47647	47873-52941	0.10
0.09	23295-26052	26471-29605	31765-35526	37059-41447	42353-47368	47648-53289	52942-59210	0.09
0.08	26053-29552	29606-33582	35527-40298	41448-47014	47369-53731	53290-60447	59211-67164	0.08
0.07	29553-34137	33583-38793	40299-46551	47015-54310	53732-62068	60448-69827	67165-77586	0.07
0.06	34138-40408	38794-45918	46552-55102	54311-64285	62069-73469	69828-82653	77587-91836	0.06
0.05	40409-49500	45919-56250	55103-67500	64286-78750	73470-90000	82654-101250	91837-112500	0.05
0.04	49501-63870	56251-72580	67501-87096	78751-101612	90001-116129	101251-130645	112501-145161	0.04
0.03	63871-90000	72581-102272	87097-122727	101613-143181	116130-163636	130646-184090	145162-204545	0.03
0.02	90001-152307	102273-173076	122728-207692	143182-242307	163637-276923	184091-311538	204546-346153	0.02
0.01	152308-495000	173077-562500	207693-675000	242308-787500	276924-900000	311539-1012500	346154-1125000	0.01

SCHEDULE B

WATER-OIL RATIOS

Water-Oil Ratio Penalty Factor	Table 0.0	Table 0.7	Table 0.8	Table 0.9	Water Oil Ratio Penalty Factor
1.00	0.0000-0.0199	0.0000-0.0372	0.0000-0.0558	0.0000-0.1117	1.00
0.99	0.0200-0.0316	0.0373-0.1053	0.0559-0.1580	0.1118-0.3160	0.99
0.98	0.0317-0.0524	0.1054-0.1748	0.1581-0.2622	0.3161-0.5245	0.98
0.97	0.0525-0.0737	0.1749-0.2457	0.2623-0.3686	0.5246-0.7373	0.97
0.96	0.0738-0.0954	0.2458-0.3181	0.3687-0.4772	0.7374-0.9545	0.96
0.95	0.0955-0.1176	0.3182-0.3921	0.4773-0.5882	0.9546-1.1764	0.95
0. 4	0.1177-0.1403	0.3922-0.46 6	0.5883-0.7015	1.1765-1.4030	0.94
0.93	0.1404-0.1634	0.4677-0.5448	0.7016-0.8173	1.4031-1.6346	0.93
0.92	0.1635-0.1871	0.5449-0.6237	0.8174-0.9356	1.6347-1.8712	0.92
0.91	0.1872-0.2113	0.6238-0.7043	0.9357-1.0545	1.8713-2.1130	0.91
0.90	0.2114-0.2360	0.7044-0.7867	1.0566-1.1801	2.1131-2.3602	0.90
0.89	0.2361-0.2613	0.7868-0.8710	1.1802-1.3065	2.3603-2.6130	0.89
0.88	0.2614-0.2871	0.8711-0.9572	1.3066-1.4358	2.6131-2.8716	0.88
0.87	0.2872-0.3136	0.9573-1.0454	1.4359-1.5681	2.8717-3.1362	0.87
0.86	0.3137-0.3407	1.0455-1.1356	1.5682-1.7035	3.1363-3.4070	0.86
0.85	0.3408-0.3684	1.1357-1.2280	1.7036-1.8421	3.4071-3.6842	0.85
0.84	0.3685-0.3968	1.2281-1.3226	1.8422-1.9840	3.6843-3.9680	0.84
0.83	0.3969-0.4258	1.3227-1.4195	1.9841-2.1293	3.9681-4.2587	0.83
0.82	0.4259-0.4556	1.4196-1.5188	2.1294-2.2783	4.2588-4.5566	0.82
0.81	0.4557-0.4861	1.5189-1.6206	2.2784-2.4309	4.5567-4.8618	0.81
0.80	0.4862-0.5174	1.6207-1.7249	2.4310-2.5874	4.8619-5.1748	0.80
0.79	0.5175-0.5495	1.7250-1.8319	2.5875-2.7478	5.1749-5.4957	0.79
0.78	0.5496-0.5824	1.8320-1.9416	2.7479-2.9124	5.4958-5.8249	0.78
0.77	0.5825-0.6162	1.9417-2.0542	2.9125-3.0813	5.8250-6.1627	0.77
0.76	0.6163-0.6509	2.0543-2.1698	3.0814-3.2547	6.1628-6.5095	0.76
0.75	0.6510-0.6865	2.1699-2.2885	3.2548-3.4328	6.5096-6.8656	0.75
0.74	0.6866-0.7231	2.2886-2.4104	3.4329-3.6157	6.8657-7.2314	0.74
0.73	0.7232-0.7607	2.4105-2.5357	3.6158-3.8036	7.2315-7.6073	0.73
0.72	0.7608-0.7993	2.5358-2.6645	3.8037-3.9968	7.6074-7.9937	0.72
0.71	0.7994-0.8391	2.6646-2.7970	3.99 9-4.1955	7.9938-8.3911	0.71
0.70	0.8392-0.8800	2.7971-2.9333	4.1956-4.4000	8.3912-8.8000	0.70
0.69	0.8801-0.9220	2.9334-3.0735	4.400 -4.6103	8.8001-9.2207	0.69
0.68	0.9221-0.9654	3.0736-3.2180	4.6104-4.8270	9.2208-9.6540	0.68
0.67	0.9655-1.0100	3.2181-3.3667	4.8271-5.0501	9.6541-10.1003	0.67
0.66	1.0101-1.0560	3.3668-3.5200	5.0502-5.2801	10.1004-10.5602	0.66
0.65	1.0561-1.1034	3.5201-3.6781	5.2802-5.5172	10.5603-11.0344	0.65
0.64	1.1035-1.1523	3.6782-3.8412	5.5173-5.7618	11.0345-11.5236	0.64
0.63	1.1524-1.2028	3.8413-4.0094	5.7619-6.0 42	11.5237-12.0284	0.63
0.62	1.2029-1.2549	4.0095-4.1832	6.0143-6.2748	12.0285-12.5497	0.62
0.61	1.2550-1.3088	4.1833-4.3627	6.2749-6.5441	12.5498-13.0882	0.61
0.60	1.3089-1.3644	4.3628-4.5482	6.5442-6. 224	13.0883-13.6448	0.60
0.59	1.3645-1.4220	4.5483-4.7401	6.8225-7.1102	13.6449-14.2205	0.59
0.58	1.4221-1.4816	4.7402-4.9387	7.1103-7.4081	14.2206-14.8162	0.58
0.57	1.4817-1.5433	4.9388-5.1443	7.4082-7.7165	14.8163-15.4330	0.57
0.56	1.5434-1.6072	5.1444-5.3573	7.7 66-8.0360	15.4331-16.0721	0.56
0.55	1.6073-1.6734	5.3574-5.5782	8.0361-8.3673	16.0722-16.7346	0.55
0.54	1.6735-1.7422	5.5783-5.8073	8.3674-8.7110	16.7347-17.4220	0.54
0.53	1.7423-1.8135	5.8074-6.0451	8.7111-9.0677	17.4221-18.1355	0.53
0.52	1.8 36-1.8876	6.0452-6.2922	9.0678-9.4384	18.1356-18.8768	0.52
0.51	1.8877-1.9647	6.2923-6.5491	9.4385-9.8237	18.8769-19.6475	0.51
0.50	1.9648-2.0449	6.5492-6.8164	9.8238-10.2247	19.6476-20.4494	0.50
0.49	2.0450-2.1284	6.8165-7.0948	10.2248-10.6422	20.4495-21.2844	0.49
0.48	2.1285-2.2154	7.0949-7.3848	10.6423-1 .0772	21.2845-22.1545	0.48
0.47	2.2155-2.3062	7.3849-7.6874	11.0773-11.5311	22.1546-23.0622	0.47
0.46	2.3063-2.4009	7.6875-8.0032	11.5312-12.0048	23.0623-24.0097	0.46
0.45	2.4010-2.5000	8.0033-8.3333	12.0049-12.5000	24.0098-25.0000	0.45
0.44	2.5001-2.6035	8.3334-8.6786	12.5001-13.0 79	25.0001-26.0358	0.44
0.43	2.6036-2.7120	8.6787-9.0401	13.0180-13.5602	26.0359-27.1204	0.43
0.42	2.7121-2.8257	9.0402-9.4191	13.5603-14.1286	27.1205-28.2573	0.42
0.41	2.8258-2.9450	9.4192-9.8168	14.1287-14.7252	28.2574-29.4505	0.41
0.40	2.9451-3.0704	9.8169-10.2347	14.7253-15.3521	29.4506-30.7042	0.40
0.39	3.0705-3.2023	10.2348-10.6743	15.3522-16.0115	30.7043-32.0231	0.39
0.38	3.2024-3.34 2	10.6744-11.1374	16.0116-16.7062	32.0232-33.4124	0.38
0.37	3.3413-3.4878	11.1375-11.6260	16.7063-17.4390	33.4125-34.8780	0.37
0.36	3.4879-3.6426	11.6261-12.1421	17.4391-18.2131	34.8781-36.4263	0.36
0.35	3.6427-3.8064	12.1422-12.6881	18.2 32-19.0322	36.4264-38.0645	0.35
0.34	3.8065-3.9800	12.6882-13.2668	19.0323-19.9003	38.0646-39.8006	0.34
0.33	3.9801-4.1643	13.2669-13.8812	19.9004-20.8219	39.8007-41.6438	0.33
0.32	4.1644-4.3604	13.8813-14.5347	20.8220-21.8021	41.6439-43.6042	0.32
0.31	4.3605-4.5693	14.5348-15.2311	21.8022-22.8467	43.6043-45.6934	0.31
0.30	4.5694-4.7924	15.2312-15.9748	22.8468-23.9622	45.6935-47.9245	0.30
0.29	4.7925-5.0312	15.9749-16.7708	23.9623-25. 562	47.9246-50.3125	0.29
0.28	5.0313-5.2874	16.7709-17.6248	25.1563-26.4372	50.3126-52.8744	0.28
0.27	5.2875-5.5630	17.6249-18.5434	26.4373-27.815	52.8745-55.6302	0.27
0.26	5.5631-5.8602	18.5435-19.5342	27.8152-29.3013	55.6303-58.6026	0.26
0.25	5.8603-6.18 8	19.5343-20.6060	29.30 4-30.9090	58.6027-61.8181	0.25
0.24	6.1819-6.5308	20.6061-21.7693	30.9091-32.6540	61.8182-65.3080	0.24
0.23	6.5309-6.9108	21.7694-23.0363	32.6541-34.5544	65.3081-69.1089	0.23
0.22	6.9109-7.3264	23.0364-24.4214	34.5545-36.632	69.1090-73.2642	0.22
0.21	7.3265-7.7826	24.4215-25.9420	36.6322-38.9130	73.2643-77.8260	0.21
0.20	7.7827-8.2857	25.9421-27.6190	38.9131-41.4 85	77.8261-82.8571	0.20
0.19	8.2858-8.8433	27.6191-29.4779	41. 286-44.2168	82.8572-88.4337	0.19
0.18	8.8434-9.4649	29.4780-31.5498	44.2 69-47.3248	88.4338-94.6496	0.18
0.17	9.4650-10.1621	31.5499-33.8738	47.3249-50.8108	94.6497-101.6216	0.17
0.16	10.1622-10.9496	33.8739-36.4988	50.8109-54.7482	101.6217-109.4964	0.16
0.15	10.9497-11.8461	36.4989-39.4871	54.7483-59.2307	109.4965-118.4615	0.15
0.14	11.8462-12.8760	39.4872-42.9201	59.2308-64 801	118.4616-128.7603	0.14
0.13	12.8761-14.0714	42.9202-46.9047	64.3802-70.3571	128.7604-140.7142	0.13
0.12	14.0715-15.4757	46.9048-51.5857	70.3572-77 786	140.7143-154.7572	0.12
0.11	15.4758-17.1489	51.5858-57.1631	77.3787-85 446	154.7573-171.4893	0.11
0.10	17.1490-19.1764	57.1632-63.9215	85.7447-95.8823	171.4894-191.7647	0.10
0.09	19.1765-21.6842	63.9216-72.2807	95.8824-108.42 0	191.7648-216.8421	0.09
0.08	21.6843-24.8656	72.2808-82.8855	108.4211-124.3283	216.8422-248.6567	0.08
0.07	24.8657-29.0344	82.8856-96.7816	124.3284-145. 724	248.6568-290.3448	0.07
0.06	29.0345-34.7346	96.7817-115.7823	145.1725-173.6734	290.3449-347.3469	0.06
0.05	34.7347-43.0000	115.7824-143.3333	173.6735-215.0000	347.3470-430.0000	0.05
0.04	43.0001-56.0645	143.3334-186.8817	215.0001-280.3225	430.0001-560.6451	0.04
0.03	56.0646-79.8181	186.8818-266.0606	280.3226-399.0909	560.6452-798.1818	0.03
0.02	79.8182-136.4615	266.0607-454.8718	399.0910-682.30 7	798.1819-1364.6154	0.02
0.01	136.4616-448.0000	454.8719-1493.3334	682.3078-22 0.0022	1364.6155-4480.0044	0.01

SCHEDULE C

AVERAGE DAILY GAS ALLOWABLE Mscfd.*

Current Average Daily Oil Production Bbls. Clean Oil	Area Assigned 10 Acres	Area Assigned 20 Acres	Area Assigned 30 Acres	Area Assigned 40 Acres	Area Assigned 50 Acres	Area Assigned 60 Acres	Area Assigned 70 Acres	Area Assigned 80 Acres	Area Assigned 90 Acres	Area Assigned 100 Acres	Area Assigned 110 Acres	Area Assigned 120 Acres	Area Assigned 130 Acres	Area Assigned 140 Acres	Area Assigned 150 Acres	Area Assigned 160 Acres
0	40	64	88	112	136	160	184	208	232	256	280	304	328	352	376	400
1	39	63	86	109	132	155	179	202	225	248	271	295	318	341	364	387
2	39	61	84	106	128	151	173	196	218	240	263	285	308	330	352	375
3	38	60	81	103	124	146	168	189	211	232	254	276	297	319	340	362
4	37	58	79	100	121	141	162	183	204	225	245	266	287	308	329	349
5	37	57	77	97	117	137	157	177	197	217	237	257	277	297	317	337
6	36	55	74	94	113	132	151	170	190	209	228	247	266	286	305	324
7	35	54	72	91	109	127	146	164	183	201	219	238	256	275	293	311
8	35	52	70	88	105	123	140	158	176	193	211	228	246	264	281	299
9	34	51	68	84	101	118	135	152	168	185	202	219	236	252	269	286
10	33	49	65	81	97	113	129	145	161	177	193	209	225	241	257	273
11	33	48	63	78	94	109	124	139	154	170	185	200	215	230	246	261
12	32	46	61	75	90	104	118	133	147	162	176	190	205	219	234	248
13	31	45	59	72	86	99	113	127	140	154	167	181	195	208	222	235
14	31	44	56	69	82	95	108	120	133	146	159	172	184	197	210	223
15	30	42	54	66	78	90	102	114	126	138	150	162	174	186	198	210
16	29	41	52	63	74	85	97	108	119	130	141	153	164	175	186	197
17	29	39	50	60	70	81	91	102	112	122	133	143	154	164	174	185
18	28	38	47	57	66	76	86	95	105	114	124	134	143	153	162	172
19	27	36	45	54	63	71	80	89	98	107	115	124	133	142	151	159
20	27	35	43	51	59	67	75	83	91	99	107	115	123	131	139	147
21	26	33	40	48	55	62	69	76	84	91	98	105	112	120	127	134
22	25	32	38	45	51	57	64	70	77	83	89	96	102	109	115	121
23	25	30	36	42	47	53	58	64	70	75	81	86	92	98	103	109
24	24	29	34	38	43	48	53	58	62	67	72	77	82	86	91	96
25	23	27	31	35	39	43	47	51	55	59	63	67	71	75	79	83
26	23	26	29	32	36	39	42	45	48	52	55	58	61	64	68	71
27	22	24	27	29	32	34	36	39	41	44	46	48	51	53	56	58
28	21	23	25	26	28	29	31	33	34	36	37	39	41	42	44	45
29	21	22	22	23	24	25	26	26	27	28	29	30	30	31	32	33
30	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Over 30**	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20

* Mscfd. - Thousands of Standard Cubic Feet Per Day.

** Only with the written authority of Board or authorized representative.